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THE SEASONAL CYCLES OF ASH, CARBOHYDRATE AND NITROGENOUS CONSTITUENTS IN THE TERMINAL SHOOTS OF APPLE TREES AND THE EFFECTS OF FIVE VEGETATIVELY PROPAGATED ROOTSTOCKS ON THEM

I. TOTAL ASH AND ASH CONSTITUENTS*

By V. G. VAIDYA
Long Ashton Research Station, University of Bristol

INTRODUCTION.

THE present paper is the first of a series of three describing the results of three related investigations†, carried out simultaneously on materials derived from common samples of terminal shoots of apple trees, taken at monthly intervals over the period January 1934 to January 1935.

They are an extension of those previously reported by Karmarkar (10), Smyth (15) and Warne and Wallace (17) on seasonal cycles of chemical constituents of terminal shoots of apple trees and the effects of rootstocks on the chemical composition of such shoots.

Hitherto the work relating to seasonal cycles had been confined to nitrogenous and carbohydrate fractions and had not included ash constituents, so that the results reported herein for the latter are without parallel. The three papers together provide a fairly complete picture of the cycles of the constituents of the three most important groups concerned with nutritional processes, and should provide a basis for considering many important nutritional problems. The results relating to ash constituents already seem to be of importance in the diagnosis of practical nutritional problems concerning supplies of the chief ash constituents.

The section of the investigations concerning rootstocks was undertaken to see whether marked differences in seasonal cycles could be associated with particular effects attributed to various rootstocks. With this end in view, five Malling rootstocks were selected which might be expected from pomological performance to show points of difference, viz.: Nos. II and V, as producing

* This paper embodies the results of an investigation presented in a thesis for the Degree of Doctor of Philosophy in the University of Bristol, December 1937. The full thesis is deposited in the Library of the University of Bristol, where it can be consulted.

† Dr. T. Wallace has been responsible for the general direction and co-ordination of the three investigations and has contributed this introduction.

trees of intermediate size and requiring good conditions of potash nutrition; No. VII, with definite dwarfing tendencies and also susceptible to potash deficiency; No. IX, as outstanding in producing dwarfing effects; and Malling B, as a representative of the strong rootstock group.

The actual trees used, variety Lane's Prince Albert, had been grown under favourable conditions as regards soil, and manurial and cultural treatments. Detailed pomological records of the trees were available since their planting which showed that the rootstocks had produced significant growth differences; hence it was possible to ascertain to what extent these were associated with differences in seasonal cycles. The results for ash constituents show that the seasonal cycles are apparently affected by rootstocks; thus, the cycles of total ash and phosphoric acid reported herein for No. IX rootstock are approximately one month in advance of those for the other stocks examined.

EXPERIMENTAL.

(1) Materials.

The apple trees from which the materials were obtained are growing on Plot 7b, a rootstock plot, at the Long Ashton Research Station. The plot consists of eight trees each of Lane's Prince Albert, Worcester Pearmain and Bramley's Seedling, worked on each of twelve vegetatively propagated rootstocks, but only Lane's Prince Albert, on rootstocks M.II, M.V, M.VII, M.IX and M.B, is considered here. The trees were planted as maidens during the winter 1919-20. All those on any given stock comprise a complete row running north to south. Measurements of the trees used were taken in March 1935 and the data, examined statistically, showed that rootstock effect was highly significant. Trees on M.IX were much smaller than the others, and those on M.VII were less than those on M.II, M.V and M.B (Table II).

The soil of the plot is mainly derived from Keuper Marl with a thin surface wash of fine sandy material (also of Triassic origin), and natural drainage is satisfactory. It appears to be of fairly uniform character, and differences in the sizes of the trees due to soil variation were proved by statistical analysis to be not significant.

Until 1928, the trees were grown under arable conditions. In that year the plot was grassed down to check vegetative growth; since then the trees have been under a system of grass culture.

The manurial treatment of the plot since planting has maintained potash supply at a high level, while the cultural practices and nitrogenous dressings have ensured adequate but not excessive nitrogen supplies.

The growth and appearance of the trees since planting suggest that there has been no deficiency of nitrogen, phosphate or potash at any time, although

before grassing down, the trees were possibly somewhat over-nitrogenous and vegetative.

Prior to the investigation the trees on all stocks had been pruned as "regulated" trees, leaders being shortened and lateral growths thinned. In 1934 pruning was carried out immediately after the May sampling. The "regulated" method was again followed, but all terminals likely to produce growths suitable for sampling later were cut back to near the base of the previous season's growth.

During 1934, when the investigation on the shoots was carried out, there was a heavy crop of blossom on all the trees. They were not sprayed in that year, and as the damage due to Sawfly was severe there was practically no crop on the trees on any stock.

(2) FIELD SAMPLING.

Eight trees on each of the rootstocks mentioned were available, and samples for chemical analysis were obtained at monthly intervals, always in fine weather, when the leaves and shoots were dry. An effort was always made to collect the samples for each month on consecutive days in the order M.II, M.V, M.VII, M.B and M.IX. On no occasion was there an appreciable interval between the collection of the comparable samples. In order to avoid diurnal fluctuations in the composition of the shoots, sampling was invariably carried out between 10.30 a.m. and 11.30 a.m.

The shoots selected for analysis on each occasion were current season's growths, usually leader shoots. More than sixty shoots, averaging eight from each of the eight trees on any one stock, were gathered for each sample for the determination of nitrogen, carbohydrates and ash. The last named only are considered in this paper.* During the young shoot stage fifteen shoots were taken from each tree to ensure a sufficient quantity of the sample. Mulay's work shows that the number of shoots gathered is likely to be sufficient to give a representative sample. Samples of stock M.IX were obtained from only five trees. Owing to the remarkably low vegetative growth on this stock, difficulty was experienced in obtaining sufficiently large samples, hence only seven samples, one in February and one each from May to October inclusive, were taken.

Immediately on cutting, each sample was wrapped in waterproof paper and conveyed to the laboratory where it was prepared for analysis without delay.

(3) LABORATORY SAMPLING.

At the laboratory the shoots were first wiped clean with a dry cloth. The weight of the sample was taken and the lengths of the individual shoots

* The results for carbohydrates and nitrogen will be reported in Parts II and III of this Series.

measured. The shoots were always separated into bark and wood portions, but when leaves were present the shoots were divided into three portions, bark + petioles, wood, and laminae of leaves.

The samples were divided into four parts for the determination of nitrogen, carbohydrates, ash and dry matter respectively. The portions kept for the estimation of ash and its constituents were dried at 100° C. and preserved in well-stoppered glass bottles.

Determinations of percentage of dry matter in wood, bark and leaves were carried out on small quantities of samples. Total weights of dry bark, dry wood and dry leaves were calculated for the estimation of ratios of dry bark to dry wood and dry leaves to dry shoots.

(4) Chemical Methods.

Estimations were made of the following constituents: carbonate ash; lime (CaO); magnesia (MgO); potash (K_2O); phosphoric acid (P_2O_5); soda (Na_2O); iron oxide (Fe_2O_3); alumina (Al_2O_3); silica (SiO_2); and manganese tetra-oxide (Mn_3O_4).

The methods used were modifications of those recommended by the Association of Official Agricultural Chemists, 1930.

(5) Accuracy of the Methods.

Duplicate determinations were carried out on about thirty samples to test the accuracy of the methods, and then single estimations only were made for the remaining samples, in view of the degree of accuracy shown. The maximum difference found in carbonate ash was not more than 1·5 per cent. of the mean value. With lime, magnesia, potash and phosphoric acid there was rarely a larger difference than 2 per cent. of the mean value, while for the minor ash constituents the duplicates generally showed a difference of 3·5 per cent. from the mean.

The differences between any two samples necessary for statistical significance were much higher than the maximum differences found between any two duplicates.

RESULTS.

Details relating to the dates of collection and the condition of the shoots at those times are given in Table I. The shoots for the various stocks were generally similar to one another at any date excepting those for rootstock M.IX which usually showed evidence of an earlier cycle.

The chemical results were calculated as percentages of ash and residual dry weight. The former method gives some idea of the variations in the composition of the ash throughout the season, whilst the latter shows the cycles

of the constituents in relation to the structural portion of the total dry matter of the plant.

Those expressed on a residual dry matter basis were subjected to statistical analysis to determine significant differences due to season and rootstocks. The minor ash constituents Na_2O, Fe_2O_3, Al_2O_3, Mn_3O_4 and SiO_2 were not considered in detail since a superficial examination of the data did not show any well defined points.

The general features of the cycles for total ash and ash constituents expressed as percentages of each in residual dry weight, are shown graphically

TABLE I.

*Data Relating to the Condition of the Shoots on the Various Sampling Dates.**

Month and Date.	Condition of Shoots.	
	Stocks M.II, M.V, M.VII and M.B	M.IX
1934 January 4	Dormant.	
February 5	Dormant.	Dormant.
March 7	Dormant.	
April 9	Bud burst. Terminal buds open.	
May 7	Pink blossom stage, shoot buds broken to small leaves. No shoot growth.	Full pink blossom stage. Several clusters near terminals. Shoot buds broken to small leaves. No shoot growth.
June 18	First new shoots, green and succulent and with fully grown leaves.	First new shoots, green and succulent and with fully grown leaves.
July 16	No terminal buds yet, shoots hard except tips, 2″-2½″.	Terminal buds beginning to form. Shoots hard to tips. Shoots not as long as on other stocks.
August 20	Terminal buds appearing. Shoots hard to tips. No secondary growth.	Terminal buds more developed. Shoots hard to tips. No secondary growth.
September 18	As August 20th. Fruit picked.	Marked fall in shoot length. Rest as August.
October 22	No autumnal tints on leaves and no defoliation of terminal shoots.	Foliage very slight tinting; slight defoliation of old wood but no appreciable defoliation of terminal shoots. Trees with very few terminal shoots.
November 20	Defoliation half-way up terminal shoots. Leaves near tips of shoots tinted brown and yellow.	
1935 January 2	Dormant.	

* Data given refer to sampling dates for M.II (see page 103).

in Fig. 1. The values for each constituent are means for the four rootstocks M.II, M.V, M.VII and M.B.

In considering the curves it should be noted that the values for May and June have been joined together for convenience of following the cycles, but actually this period marks the passing from the old to the new terminal growths.

DISCUSSION.

Three aspects of the data require discussion, viz. (a) seasonal cycles, (b) stock differences and (c) double interaction of factors.

(a) Seasonal Cycles.

For purposes of discussion it is advisable to divide the year covered by the investigation into periods corresponding to well defined physiological states of the tree. The division adopted was that described by Karmarkar (10):—

(1) *Period of bud swelling*—approximately April and May.

(2) *Period of shoot elongation*—June, July and part of August.

(3) *Period of full growth*—late August, September and most of October.

(4) *Period of leaf fall*—late October and November.

(5) *Period of dormancy*—December, January, February and March.

Cycles of Individual Constituents.

Bark and Wood.

Water content of shoots. The water content increases during the period of bud swelling. With the appearance of young shoots in June it is at a maximum and then falls off steadily, reaching a low level from October onwards, the values fluctuating only between 50 and 53 per cent. during the dormant period. These figures agree closely with Karmarkar's values for Newton Wonder on grass and arable plots at Long Ashton.

Percentage of bark in shoots. The percentage of bark, about 75, is very high in the young shoots, but as they become mature the percentage of wood increases and that of the bark falls to about 50 by the end of August. During the rest of the season the bark constitutes 45-50 per cent. of the total dry matter of the shoots.

Carbonate ash. The cycles of ash for wood and bark are different in character. The changes in ash content of wood are smoother than those in bark. The values for bark are always higher than those for wood, the former ranging from 9·04 to 7·75 per cent. and the latter from 4·39 to 1·255 per cent.

In the wood, ash content slightly decreases during the period of bud swelling. The young shoots in June are very rich in total ash, but the content

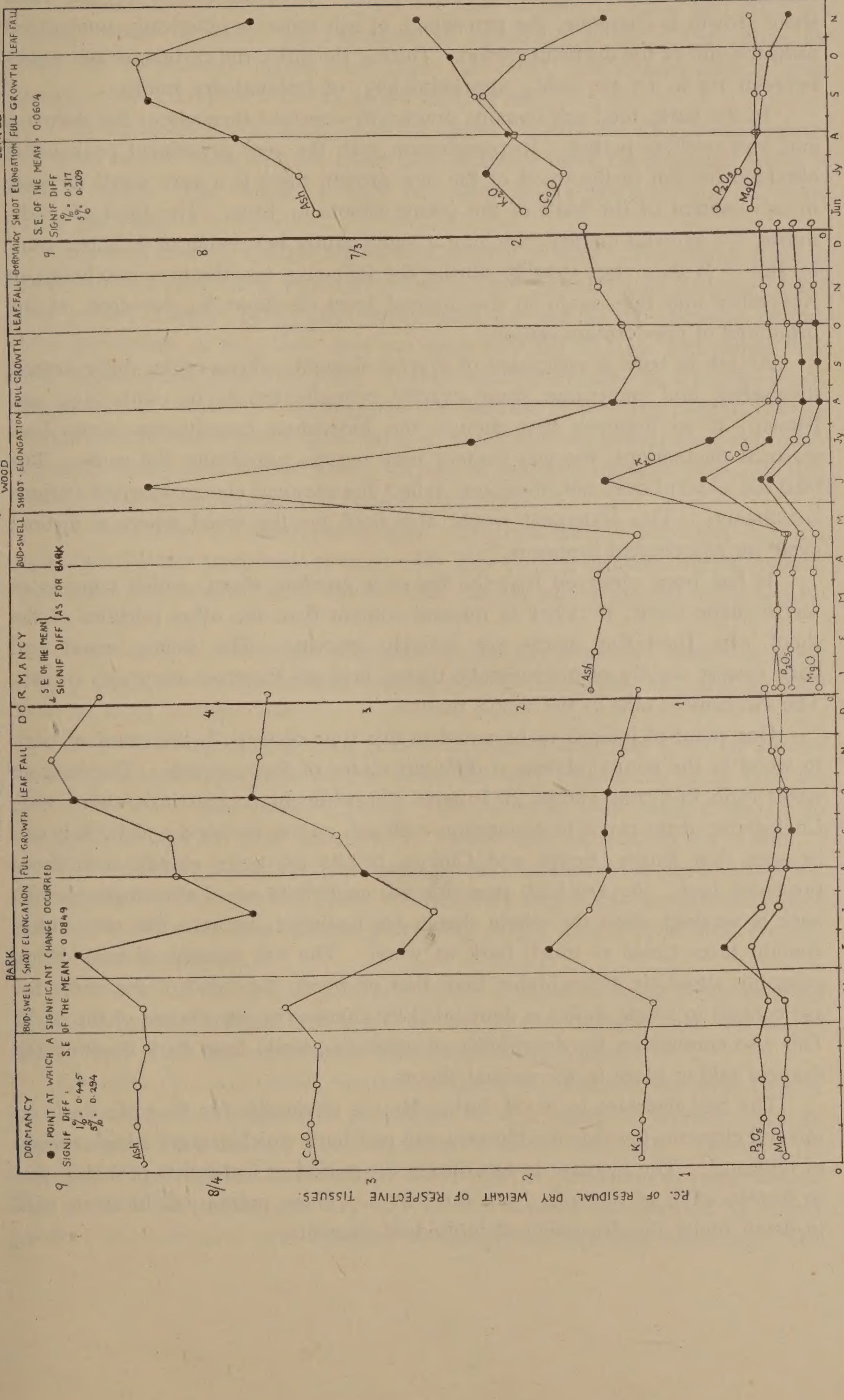
AVERAGE SEASONAL CYCLES (STOCKS II, V, VII, M.B)
BARK
WOOD
LEAVES
DORMANCY
BUD-SWELL
SHOOT ELONGATION
FULL GROWTH
LEAF FALL
● - POINT AT WHICH A SIGNIFICANT CHANGE OCCURRED
SE OF THE MEAN - 0·0849
SIGNIF DIFF: 1% - 0·445, 5% - 0·294
SE OF THE MEAN & SIGNIF DIFF AS FOR BARK
S.E. OF THE MEAN - 0·0604
SIGNIF DIFF 1% - 0·317, 5% - 0·209
Ash
CaO
K₂O
P₂O₅
MgO
J F M A M J Jy A S O N D
P.C. OF RESIDUAL DRY WEIGHT OF RESPECTIVE TISSUES.

FIG. 1.

rapidly falls as the shoots become more mature. From the end of August, when shoot growth is complete, the percentage of ash remains practically unchanged until the end of the dormant period. During the latter the carbonate ash varies between 1·4 to 1·7 per cent., approximately, of residual dry matter.

In the bark, total ash remains practically constant throughout the dormant and bud swelling period. In comparison with the very prominent peak value obtained for ash in the wood of the new growth there is a very small increase in ash content of the bark of the young shoots in June. The total ash falls during the growing period, reaching a significantly low value of 7·75 per cent. in July. It then rises steadily during the following months to a maximum in November and falls again to the original level of about 8·1 per cent. at the beginning of the dormant season.

As ash in bark is composed of several elements whose cycles differ among themselves and sometimes show exactly opposite trends (as with lime and potash), it so happens that though the individual constituents may show seasonal fluctuations, the ash content may remain practically the same. The total ash content does not, therefore, reflect the seasonal changes for the various constituents. This statement would also hold for the wood where a distinct cycle for ash content is shown.

It has been observed that the tip of a growing shoot, which consists of meristematic tissue, is richer in mineral content than the other portions of the shoot. In June the shoots are actively growing. The young wood and bark consist mainly of meristematic tissues and are therefore very rich in ash. The ash content falls as the shoots mature.

One point of interest to be noted in this type of work is the ratios of bark to wood in the annual shoots at different stages of their growth. The bark to wood ratio in young shoots in June is 4:1 while in August it is about 1:1. Considering these ratios in connection with ash curves in wood and bark it can be seen that Butler, Smith and Curry's results (2) agree closely with those presented here. A very high peak for ash content in wood as compared with bark is masked when the whole shoots are analysed, because the new shoots contain three times as much bark as wood. The ash content of bark being generally about six times higher than that of wood, the trend of the curve for ash content in whole shoots is dominated by changes in ash content of the bark. This also emphasizes the desirability of separating wood from bark to study the changes taking place in the annual shoots.

The first decrease in wood during May is obviously due to a big draft on mineral elements towards the blossom and leaf-buds which require a high supply of nutrients. The increase in ash during the period of leaf-fall is probably due to translocation of minerals from the leaves. These points will be dealt with in detail under the discussion of individual elements.

Lime. The forms of the cycles for lime content of wood and bark are similar when the results are expressed as percentage of ash. The values for bark are consistently higher than those for wood, the former ranging from 30-45 per cent. and the latter 13-35 per cent. of ash.

On the residual dry matter basis the cycles for bark are similar in character to those on ash basis, but for wood they resemble more the seasonal cycles of ash in wood. The values for bark vary from 2·55-4 per cent. and for wood 0·3-1 per cent.

In wood there is a slight fall in lime content in May. The young wood in June shows a peak value which decreases rapidly by the end of August. After that period it keeps practically steady until the end of the dormant period. Like percentage of ash, lime does not show any fall in May, but shows very low values during June and July. It then steadily increases to a maximum by the middle of October. This suggests that because of the high mineral content of new shoots lime shows a peak value in June, but when compared with other elements, like potash and magnesia, its ratio is definitely lower in June and July than in August, September and rest-period months.

In bark there is a small rise in May. The new bark in June and July has a significantly low percentage of lime. The lime content increases during August, September and October, after which it keeps steady during the rest of the season.

Potash. The percentage of potash in the ash is always higher in wood than in bark, the values in bark varying from 13 to 23 per cent. and in wood from 20 to 35 per cent. ash.

On residual dry weight basis, seasonal cycles in bark and wood are similar to the corresponding cycles on ash basis, the only differences being that the former have a higher peak in June. The values in bark range from 1·2 to 1·9 per cent. and in wood from 0·27 to 1·4 per cent. of residual dry weight.

In wood there is a slight decrease in potash content during the bud swelling period, followed by a peak in June. During July and August the potash content falls to 0·4 per cent. and remains practically steady at that level until the end of the dormant period.

The seasonal changes in bark are similar to those in wood except that the values for potash remain high until the end of October and then fall to the steady level of 1·2 per cent. during November and December.

Chandler (3), and Butler, Smith and Curry (2) obtained the same type of curves for potash, expressed as percentage of dry matter, in annual shoots of apple trees. They did not, however, separate wood from bark. Dowding (5) has studied the regional and seasonal distribution of potassium in plant tissues. The meristematic tissues are very rich in this element as indicated by strong positive microchemical tests obtained in the growing tips and cambium. The

high peak in June from the first sample of the new growth is, therefore, only to be expected. As shoots mature, the potash content falls rapidly in wood but more gradually in bark. The fact that the bark is a very active tissue of the tree and includes the cambium, may be associated with this high potash content in bark as compared with wood during the period July to October.

The potash in bark and wood has been shown to decrease in May. Blossom and leaf-buds develop rapidly during this period and require a large supply of potash. Naturally there must be a heavy draft on potash from the shoots. Hooker (9) has observed an increase in potash content of all types of spurs in May, but this increase in non-bearing and barren spurs is not marked, while in bearing spurs there is an increase of almost 66 per cent.

It is useful here to examine the potash contents in relation to those for lime. The peak value for potash in June corresponds to a minimum value for lime. Curves for lime and potash, expressed as percentages of ash, appear in a general way as reciprocals of one another. There is a very high negative correlation between them. When the curves for them are drawn on a residual dry weight basis they show only a slight negative correlation for bark and none at all for wood. Wallace (16) and others have observed an increase in percentage of lime when the plants were starved for potash, and vice versa. The chemical significance of this is not known.

Magnesia. On percentage of ash basis the curves for bark and wood are dissimilar. The values are always higher in wood than in bark and vary from 4 to 9·6 per cent. in wood and 3·4 to 8·4 per cent. in bark.

In wood the magnesia content shows a steady increase throughout the dormant period. There is no pronounced peak in June. The percentage of magnesia decreases during the period of shoot elongation, reaches its minimum between August and September, and, after the shoots have ceased to elongate, begins to rise, steadily reaching the normal level at the beginning of the period of dormancy. The curves for bark resemble those plotted on residual dry weight basis.

The seasonal cycles of magnesia expressed as percentages of residual dry weight are similar in character in bark and wood. The values are from 0·341 to 0·741 per cent. in bark and from 0·066 to 0·4 per cent. in wood.

The young shoots in June show a peak value which decreases gradually to the end of September and then remains steady till the end of the dormant period.

Phosphoric acid. As percentage of phosphoric acid in ash, the wood always shows higher values than the bark, varying from 9 to 20 per cent. in wood and from 3·4 to 8·6 per cent. in bark.

When the results are expressed as percentages of residual dry matter, phosphoric acid content in bark is higher than in wood. The values range from 0·299 to 0·56 per cent. in bark and from 0·172 to 0·451 per cent. in wood.

In the wood there is a decrease in May followed by a peak in June. The phosphoric acid decreases during the following months, reaches a minimum in the middle of August and September and then begins to rise steadily, becoming relatively high again at the beginning of the period of dormancy. On percentage of ash basis it shows a fall in May and very low values in June and July. It then increases during the following months to the high level of 15 per cent. before the beginning of the dormant period.

In the bark on residual dry matter basis there is a fall in May followed by a somewhat higher value in June. The increase is relatively small compared with the pronounced peak value for June in wood. The phosphoric acid falls steadily till the end of September when it reaches a significantly low value of 0·299 per cent. ; then follows a gradual increase to a value of 0·459 per cent. at the end of December, and this is maintained during the dormant season. The cycle on the basis of ash is similar to that on residual dry weight basis.

The seasonal changes of phosphoric acid in bark and wood are very similar to those reported for total nitrogen and protein nitrogen by Karmarkar (10) in his studies on apple shoots from grass and arable plots. Butler, Smith and Curry (2), working on trunk, branches and new growths of apple trees, and Hooker (9), working on bearing, non-bearing and barren spurs of apple trees, found a similar parallelism between phosphorus and nitrogen curves. Miss Brown (1), however, working on apple fruits, did not find any relationship between nitrogen and phosphorus. She thinks that a fleshy organ like an apple, with low protoplasmic content, has only a small percentage of its phosphorus in organic form. A positive correlation of this kind between nitrogen and phosphoric acid in shoots suggests that the elements are mainly present in the same molecules. Since nucleic acid, lecithin and allied substances contain both of these elements, the bulk of the phosphoric acid in these organs may be present in organic form.

Phosphoric acid in wood and bark has been shown to decrease in May when blossom and leaf-buds are on the shoots. Phosphoric acid must be translocated to these developing blossom and leaf-buds. Hooker (9) found an increase in phosphorus content of bearing spurs during early spring, in sharp contrast to the non-bearing and barren spurs.

Soda, iron oxide, alumina, manganese oxide and silica. These substances do not show any well defined seasonal cycles, the values for all remaining practically constant throughout the year.

LEAVES.

Water content. The water content is highest in the new leaves and falls as they become mature, the values ranging between 56 and 60 per cent. during August, September and October. There is a rise in water content during defoliation in November, but this may be apparent rather than real since it has been shown that the leaves lose dry matter constituents during this period.

Percentage of dry leaves in dry shoots. The proportion of dry leaves to dry shoots over the period of foliation varies approximately from 70 to 40 per cent., decreasing steadily as growth proceeds.

Total Ash. The values for ash vary from 7·28 to 8·36 per cent. of residual dry matter. The quantity of ash is least in new leaves; it shows a significant rise during each month from August to October and then a significant drop during November. It should be noted that this drop is shown, although the dry matter also drops during this period.

The rise in ash content is mainly due to accumulation of lime, and the fall during November is due to migration of potash and phosphoric acid from leaves to shoots.

Sampson and Semisch (14) have studied the seasonal changes in the composition of oak leaves. Although they expressed their results on the basis of "specific organ", e.g. as grammes of ash per 1,000 leaves, the trend of the curves is similar to those obtained in the present work on apple leaves.

Lime. The cycles of lime expressed as percentage of ash are similar to those expressed on the basis of residual dry matter. As percentage of residual dry matter the values range from 1·69 to 2·63.

There is a fall in lime content in July, after which it increases steadily during the following months. The curves obtained do not show any migration of lime before leaf-fall. Sampson and Semisch (14) also found that calcium continued to accumulate. Richter's results (13) on leaves of apple, pear, plum and cherry agree with those reported here.

There are available many determinations of total and water-soluble calcium, cf. Haas and Halma (6). Soluble calcium as percentage of dry matter in citrus leaves was found to be practically constant as compared with the total calcium, which showed a steady increase over the one-year period covered by the investigation. This means that calcium is continuously being rendered insoluble in the leaves and is stored there in that form. The results, however, provide no information as to the actual calcium compounds present.

Potash. The values for potash as percentage of ash again show a very high negative correlation with those for lime. In the leaves, the potash content is higher than the lime content in June and July, is equal to it in August and

September, and less in October and November. The values on the residual dry matter basis range from 1·43 to 2·21 per cent. of residual dry matter.

The values for potash increase significantly during the period of rapid growth, remain high during the period of full growth, reach a peak in September and finally fall rapidly to the very low value of 1·43 per cent. in November.

These results agree with those of Sampson and Semisch (14) on oak leaves, Chandler (3) on apple leaves, and Richter (13) on apple, pear, cherry and plum leaves.

Leaves contain about 45-50 per cent. of total potash in the annual shoot growth from June to October. The fact that the seat of photosynthetic activity is in the leaves may be associated with the high concentration, since potash is considered to play a part in carbohydrate synthesis.

Magnesia. The magnesia expressed as percentage of residual dry matter does not show any significant seasonal changes. The values vary from 0·46 to 0·5 per cent. of residual dry matter. When expressed on percentage of ash basis, new leaves contain high amounts of magnesia which decrease steadily during the following months, but finally rise in November. The figures do not indicate any transference of magnesia from leaves to shoots before leaf-fall.

Phosphoric acid. The cycles for phosphoric acid expressed as percentage of ash and percentage of residual dry matter are similar. The new leaves contain a very high amount of phosphoric acid which decreases steadily to a minimum of 0·24 per cent. of residual dry matter at the time of leaf-fall.

These results agree with those of Richter (13). The curves show a regular fall throughout the season, whereas total nitrogen and protein nitrogen fall sharply during October and November. It seems possible, from the shape of the curves, that migration of phosphoric acid from the leaves commences earlier than that of potash, but it should be remembered that phosphoric acid is usually taken into vegetative organs of plants at an early stage during growth and thus the apparent fall shown from the early stage in this case may be due to the accumulation of dry matter in the leaves. Thus, the curves indicate a very steep fall in phosphoric acid content during the actual growing period to the middle of August, then a slower rate of fall during the full growth period, followed by a sharp fall again during the leaf-fall period. Sampson and Semisch (14), working on oak leaves, have observed an earlier migration of phosphoric acid.

Soda, iron oxide, alumina, manganese oxide and silica. These do not show any definite seasonal cycles. On ash basis the contents remain practically constant, although silica shows a slight accumulation.

Summary of Composition of the Terminal Shoots at Certain Stages of Development during the Year.

The conditions of the shoots at the five periods corresponding to the various important physiological stages are shown diagrammatically in Fig. 1, where the cycles for ash and all the principal constituents have been plotted on a common scale. The data for wood, bark and leaves are all on the basis of residual dry matter, the values plotted being those for which significance has been determined.

(1) Dormancy (December, January, February, March). As the first sample was gathered in January, it is best to follow the cycle from this period. The ash and its constituents do not show any significant changes during this long period.

(2) Bud Swelling (April, May). There are two samples representing this period. There are no changes in April from the values in the dormant season. During May ash and all the chief ash constituents considered tend to show a decrease in wood whilst in the bark, ash and magnesia do not change, but lime tends to increase and potash and phosphoric acid to decrease.

(3) Shoot Elongation (June, July and part of August).

Bark and wood. At the beginning of the period, the young shoots show maxima for water, ash, potash, phosphoric acid (not significant in bark) and magnesia content, whilst lime is at a minimum in bark and maximum in wood. Throughout the period potash, phosphoric acid and magnesia decrease in bark and wood. Ash and lime also show a continuous decrease during this time in wood, but in bark they fall in July and increase in August.

Leaves. Ash increases at first slowly and then more quickly. Lime falls in July and rises during August. Potash rises in July and remains fairly steady in August. Magnesia remains constant and phosphoric acid decreases steadily throughout the period.

(4) Period of Full Growth (end of August, September and most of October).

Bark and wood. In wood there are no significant changes, though ash and potash show a slight decrease, and lime, magnesia and phosphoric acid show a slight increase. In bark, however, ash and lime increase sharply. Potash remains steady at a higher level than in the dormant season, while magnesia decreases throughout the period. Phosphoric acid reaches its minimum in September and increases in October.

Leaves. Ash and lime increase steadily, potash rises in September and commences to fall in October. Magnesia is constant and phosphoric acid shows a steady fall.

(5) LEAF-FALL (end of October, November).

Bark and wood. There are no significant changes in wood, though ash has a slight tendency to rise. In the bark, ash and phosphoric acid continue to increase. Lime and magnesia remain practically constant and potash shows a slight decrease.

Leaves. Ash, potash and phosphoric acid show a steep fall. Lime increases and magnesia remains constant.

These results agree very closely with the findings of Mason and Maskell (12). These workers state, "Phosphorus, potassium and other ash constituents ascend the stem mainly via the wood, are re-exported from the foliage and move downwards towards the roots via the phloem. Calcium also ascends via the wood, but there is no evidence that it is re-exported from the leaf to move downwards via the phloem." The peak value in June for calcium in wood could be explained in the light of calcium translocation via the xylem. That calcium is not re-exported from the leaves may be deduced from a significantly high value in November in leaves. At the time of leaf-fall, wood does not show any rise in ash constituents while bark shows a high value for ash and phosphoric acid. Transference of potash from the bark of the young shoots to older shoots, trunk and roots may possibly account for the slight fall in bark.

(b) STOCK DIFFERENCES.

The results obtained are classified into three sub-heads for discussion: (1) tree data, (2) sampling data and (3) chemical data.

The data have been analysed statistically and the standard of significance used has been that the chances against a result being fortuitous must be at least one hundred to one.

To simplify the discussion the results are arranged in tabular form in Table II, which shows the grouping of stocks on the basis of high, medium and low values. Stocks which appear together in any one column are not significantly different from one another.

Tree data. The measurements of the trees taken at the conclusion of sampling in 1935, as regards height, stem girth at crotch and base, and spread are regarded as the criteria of vigour. The differences in height, girth and spread reflect the cumulative effects of different stocks on the same scion variety for fifteen years and, therefore, give an idea of the relative effects of the rootstocks on growth under the prevailing conditions.

If the rootstock effects are correlated with chemical composition of the shoots, then gradients in growth should be in the same or the reverse direction to those of the chemical constituents.

Sampling data. The mean length of shoots in centimetres taken at monthly intervals indicates roughly the condition of the trees as regards vegetative growth.

The trees on M.B are highly vegetative as compared with those on M.II, M.V and M.VII. The trees on M.IX are least vegetative.

The water contents of the terminal shoots on different stocks do not show any significant differences. Knight (11) found that although unworked stocks showed differences in transpiration rates, the differences were not observable in scion varieties worked upon rootstocks.

Percentages of dry bark in dry shoots (wood + bark portions only) and percentage of dry leaves in dry shoots (wood + bark + leaves) were calculated.

TABLE II.

	High.	Medium.	Low.
Tree data :			
Height	M.B, M.II, M.V	M.VII	M.IX
Stem girth (at crotch and base)	M.B, M.II, M.V	M.VII	M.IX
Cross-sectional area of spread N.S. × E.W.	M.B, M.II, M.V	M.VII	M.IX
Sampling data :			
Mean length of shoots in cm.	M.B	M.II, M.V, M.VII	M.IX
Water content of shoots ..		M.B, M.II, M.V, M.VII, M.IX	
% of dry bark in dry shoots (wood + bark portions only)	M.IX	M.VII, M.II, M.V	M.B
% of dry leaves in dry shoots (wood + bark + leaves) ..	M.IX	M.VII, M.II, M.V	M.B
Chemical data :			
Bark :			
Ash	M.IX	M.II, M.V, M.B	M.VII
Lime	M.IX	M.II, M.V, M.B	M.VII
Potash		M.B, M.II, M.V, M.VII, M.IX	
Magnesia		M.B, M.II, M.V, M.VII, M.IX	
Phosphoric acid		M.IX, M.VII, M.II, M.V, M.B	
Wood :			
Ash	M.IX	M.VII, M.II, M.V, M.B	
Lime	M.IX	M.VII, M.II, M.V, M.B	
Potash		M.B, M.II, M.V, M.VII, M.IX	
Magnesia		M.B, M.II, M.V, M.VII, M.IX	
Phosphoric acid		M.IX, M.VII, M.II, M.V, M.B	
Leaves :			
Ash	M.IX, M.B	M.II, M.V	M.VII
Lime	M.IX, M.B	M.II, M.V	M.VII
Potash	M.B	M.VII, M.II, M.V	M.IX
Magnesia		M.B, M.II, M.V, M.VII, M.IX	
Phosphoric acid		M.B, M.II, M.V, M.VII, M.IX	

From these data the stocks are arranged in the following order: M.IX>M.VII, M.II, M.V>M.B. The shoots on stock M.IX have a significantly higher bark to wood ratio and more leaves per shoot as compared with shoots on M.B. Colby (4) found similar differences in the shoots of Whitney on M.IX and Whitney on M.XII.

The sampling data classify stocks M.IX and M.B as two extremes. Other stocks range between them.

Chemical data. The grouping for various chemical constituents in wood, bark and leaves is given in Table II, and thus only the salient points of the data require further mention. In the first place it is of interest to examine the results for stock M.IX. The values for this stock for ash and lime are on the high side in all the tree tissues, wood, bark and leaves, and are far above the values necessary for significant differences. This suggests that M.IX is a high calcium stock as compared with the others. Warne and Wallace (17) also found high values for lime in the annual shoots of Worcester Pearmain and Lane's Prince Albert on M.IX. High ash content is mainly due to high lime, because lime constitutes about 40 per cent. of ash in the bark and 30 per cent. of ash in wood and leaves. Potash content is rather on the low side. If the high negative correlation between lime and potash has any chemical significance in stock M.IX, it indicates that the potash requirements of this stock are low, even when it is grown on a soil plentifully supplied with potash.

The remaining four stocks, when arranged in the order of their potash content, show the following order: M.B>M.VII, M.II, M.V. It will thus be seen that even under favourable conditions of potash supply the rootstock M.B shows a higher potash level than the other three which, under conditions of low potash supply, are more susceptible to leaf scorch ; cf. Hatton and Grubb (8).

It should be noted also that the chemical data for stocks M.II and M.V are very similar in all respects.

When the groupings for chemical data are examined in relation to the tree data, it does not appear on the surface that pomological characters show any close relationship to the chemical factors. There are indications, however, that phosphoric acid and magnesia may be correlated with vigour, phosphoric acid being negatively and magnesia positively correlated with height, girth and spread. Phosphoric acid is usually associated with fruitfulness, and it is thus of interest to note that bark and wood of annual shoots on stock M.IX contain relatively high amounts of phosphoric acid. This was also found by Warne and Wallace (17). Colby (4), on the other hand, recorded very low values for M.IX.

Magnesia is high in trees on stocks M.II, M.V and M.B and less in M.VII and M.IX, thus suggesting a negative correlation between magnesia and precocity. Further points relative to differences between stock M.IX and the other stocks are mentioned in the discussion of double interactions.

(c) Double Interaction of Factors.

The several interactions of factors for which significance has been determined by analysis of variance are as follows: Interaction between

(1) Stocks—months (2) Stocks—mineral elements (3) Months—mineral elements	In wood, bark and leaves
(4) Stocks—parts of plant (5) Mineral elements—parts of plant (6) Months—parts of plant	In wood and bark portions only

and these are discussed separately below.

(1) *Stocks and months.* The variation due to the interaction between stocks M.II, M.V, M.VII and M.B and months is not significant for wood, bark and leaves data. The seasonal cycles in these tissues for any particular mineral element are parallel. In other words, change from one month to the next has the same effect on all four stocks. Stock M.IX behaves differently. It shows similar seasonal cycles in leaves but not in wood and bark, where the interaction is significant. Earlier cycles for ash and phosphoric acid in bark are shown on stock M.IX.

Hatton and Grubb (7) found that Lane's on M.IX blossomed four or five days earlier than Lane's on M.B and consider that earlier blossoming on M.IX takes place under varied conditions of soil, climate and cultural practice. A marked fall in shoot growth of varieties on M.IX by the middle of August is also an observed fact. At present no reasoned explanation of the apparent correlation between these observations and phosphoric acid can be given, but an earlier cycle for phosphoric acid which has been associated with precocity is worth noting.

(2) *Stocks and mineral elements.* This interaction is significant in leaves, but not significant in wood and bark portions with the exception of stock M.IX. The following Tables show that for the different stocks the various elements are not in the same ratios in leaves, but are present in similar proportions in wood and bark portions of shoots on different stocks, except M.IX.

The ratios of different elements show extreme values for the wood, bark and leaves portions of shoots on stock M.IX as compared with those on other stocks. This indicates that the chemical composition of the shoots on M.IX is different from that of shoots on M.II, M.V, M.VII and M.B. The values for the ratios cannot be correlated with vigour except in bark where they are positively correlated with vigour.

(3) *Months and mineral elements.* The variation due to the interaction between months and mineral elements in wood, bark and leaves is significant.

TABLE III.

Leaves.

Ratios.	M.II	M.V	M.VII	M.B	M.IX
Ash / Lime	3·89	3·94	3·93	3·62	3·20
Potash / Phosphoric acid	3·89	3·77	4·09	4·56	3·68
Potash / Lime	0·99	0·99	1·14	0·94	0·67
Potash / Magnesia	4·14	4·19	5·29	4·21	3·85
Ash / Potash	3·92	3·99	3·45	3·85	4·79
Ash / Phosphoric acid	15·26	15·02	14·11	17·59	17·63
Lime / Phosphoric acid	3·92	3·81	3·59	4·86	5·51

TABLE IV.

Bark.

Ratios.	M.II	M.V	M.VII	M.B	M.IX
Ash / Lime	2·63	2·52	2·55	2·57	2·32
Potash / Phosphoric acid	3·60	3·59	3·62	3·87	2·34
Potash / Lime	0·435	0·410	0·463	0·433	0·304
Potash / Magnesia	3·29	3·38	4·10	3·42	3·70
Ash / Potash	6·05	6·14	5·52	5·94	7·62
Ash / Phosphoric acid	21·78	22·05	19·97	22·99	17·88
Lime / Phosphoric acid	8·28	8·76	7·82	8·94	7·72

TABLE V.

Wood.

Ratios.	M.II	M.V	M.VII	M.B	M.IX
Ash / Lime	4·06	3·98	4·43	4·36	3·38
Potash / Phosphoric acid	1·64	1·86	1·99	2·18	1·57
Potash / Lime	0·965	1·02	1·21	1·25	0·708
Potash / Magnesia	3·43	3·94	4·49	4·27	3·90
Ash / Potash	4·20	3·91	3·65	3·48	4·77
Ash / Phosphoric acid	6·90	7·27	7·26	7·58	7·48
Lime / Phosphoric acid	1·70	1·83	1·64	1·74	2·22

This means that changes from one month to another do not affect all elements in the same way. The curves for ash, lime, magnesia, potash and phosphoric acid are significantly different from one another in wood, bark and leaves. This has been dealt with in detail under the discussion of seasonal cycles.

(4) *Stocks and parts of plant.* The interaction between stocks and bark and wood portions is significant, which means that ratio of bark/wood content for all elements taken together is different for different stocks.

TABLE VI.

Showing Ratios Bark/Wood Contents for Sum of Elements for Different Stocks.

M.II	M.V	M.VII	M.B	M.IX
5·64	5·18	5·21	5·32	4·97

Stock M.IX again assumes an extreme value. Stock M.II has the highest ratio while stock M.V, M.VII and M.B range between M.II and M.IX.

(5) *Mineral elements and parts of plant.* The ratios of ash and ash constituents in bark and wood, considering all stocks together, are significantly different. The actual mean ratios are given in Table VII.

TABLE VII.

Ratios Bark/Wood Contents—Mean Values for all Stocks.

Ash.	CaO	MgO	K_2O	P_2O_5
5·40	8·55	3·89	3·46	1·91

This shows, for example, that 8·55 parts of lime are in bark per each part in wood. With potash and magnesia the concentration in bark as compared with wood is about 3·5 to 1, while with phosphoric acid, for one part in wood there are only two parts in bark.

Considering the above two interactions together, Table VIII has been prepared to show bark/wood ratios for different elements in different stocks.

TABLE VIII.

Ratios Bark/Wood Contents for Ash and Ash Constituents for Different Stocks.

Elements.	M.II	M.V	M.VII	M.B	M.IX
Ash ..	5·84	5·35	5·30	5·53	5·09
Lime ..	9·01	8·46	9·20	9·36	7·42
Magnesia ..	4·24	3·96	3·85	4·05	3·36
Potash ..	4·06	3·40	3·51	3·24	3·18
Phosphoric acid ..	1·85	1·77	1·93	1·82	2·13

This Table shows that bark/wood ratios for all elements are extreme values for stock M.IX when compared with other stocks. The ratio for M.IX is highest for phosphoric acid and lowest for ash, lime, magnesia and potash.

Bark/wood ratios for ash, magnesia and phosphoric acid are correlated with the order of vigour, ash and magnesia being shown to be positively and phosphoric acid negatively correlated with height.

(6) *Months and parts of plant.* The variation due to the interaction between months and bark and wood is significant. This means that the seasonal cycles for different elements in bark differ significantly from those in wood. This has been discussed in detail under the section of seasonal cycles.

CONCLUSIONS.

The main conclusions which may be drawn from the data obtained in the investigations are as follows:—

1. WATER CONDITIONS IN SHOOTS.

The water content of bark and wood rises through the period of bud swelling and blossoming. It is at a maximum in the young shoots in June. It subsequently decreases through the growing season to the period of autumnal

tinting in October, eventually remaining at a fairly steady level during the period of dormancy.

In the leaves the water content is highest in new leaves and decreases gradually to October, when it rises to a higher level during the period of leaf-fall.

2. Ratios of Wood, Bark and Leaves in Shoots.

The proportion of dry wood in the bark + wood portion of the shoots varies from about 25 per cent. in June to approximately 50 per cent. in the fully grown shoots.

The percentage of dry leaves in dry shoots—wood, bark and leaves—varies approximately from 70 per cent. in June to about 40 per cent. in October immediately prior to defoliation.

3. Seasonal Cycles of Ash and Ash Constituents.

Well defined cycles occur for ash, lime, magnesia, potash and phosphoric acid in wood, bark and leaves. The less important constituents, soda, iron oxide, alumina, manganese oxide and silica, do not show any significant seasonal variations in any of the three portions of the shoots.

The main features of the cycles for ash, lime, magnesia, potash and phosphoric acid may be summarized as follows:—

(i) Ash content in bark ranges from 7·75 to 9·04 per cent. and in wood from 1·255 to 4·39 per cent. residual dry weight. In bark it is high in June, falls to a minimum in July, then increases steadily to a maximum in November and later falls in December, after which no change occurs during dormancy. Ash content of wood is at a maximum in June and decreases rapidly until August, after which it remains steady.

In the leaves ash ranges from 7·28 to 8·43 per cent. residual dry weight. It rises steadily to a peak in October and then falls in November during the leaf-fall period.

(ii) Lime content in bark ranges from 2·81 to 3·75 and in wood from 0·307 to 0·834 per cent. residual dry weight. A minimum lime content in bark is found in June and July. The amount increases gradually up to November, after which it remains steady. In wood there is a peak value in June, while there are no significant changes during the remaining months.

The lime content of leaves steadily rises from about 1·69 to 2·42 per cent. residual dry weight by the end of November. There is no evidence of transference of lime into the shoots.

(iii) Potash content in bark is at a maximum in June, maintains a high level up to October and then falls to a lower steady level. Wood shows a peak in June, then the potash content falls steadily to the end of August, after which no appreciable change occurs. The values range in bark from 1·2 to 1·86 per cent. and in wood from 0·27 to 1·464 per cent. residual dry weight.

In the leaves the potash content is at a high level from June to October and shows a steep fall in November. The values vary from 1·43 to 2·21 per cent. residual dry weight.

(iv) The magnesia content of the young shoots is at a maximum in June and decreases throughout the growth period to the end of August, after which no change occurs. Bark content ranges from 0·341 to 0·741 per cent. and wood from 0·066 to 0·4 per cent. residual dry weight.

In the leaves there are no significant changes in magnesia content; it remains at a steady level of about 0·47 per cent. residual dry weight from June to November.

(v) The phosphoric acid content of young shoots is at a maximum in June and decreases steadily to a minimum in the middle of September. It increases during October and November and then remains steady. The values range in bark from 0·299 to 0·56 per cent. and in wood from 0·172 to 0·451 per cent. residual dry weight.

In the leaves it shows a steady fall from 0·65 to 0·22 per cent. residual dry weight, the minimum being reached before leaf-fall.

4. Functions of Ash Constituents.

Certain observations may be made on these results in connection with the respective functions of the constituents.

Potash and phosphoric acid are translocated to the developing blossom and leaf-buds in May. They are re-exported back from the leaves to the shoots before leaf-fall. The concentration of potash is higher in leaves and young bark than in wood, and this agrees with the view that potash is essential to photosynthesis and active growth processes.

5. Correlations and Interactions of Ash Constituents.

There is a high negative correlation between lime and potash. The curves for ash are similar to those for lime, since lime constitutes a high proportion of the ash, about 40 per cent. in bark and 30 per cent. in wood and leaves. Lime and magnesia do not appear to migrate from leaves to shoots before leaf-fall.

The various ash constituents are present in different proportions in bark and wood. The ratios of bark to wood for lime, potash, magnesia and phosphoric acid are 8·55, 3·46, 3·89 and 1·91 respectively.

New leaves are richer in potash and phosphoric acid. The seasonal cycles in bark and wood are dissimilar for ash and lime, and similar for potash, magnesia and phosphoric acid.

6. Stock Effects on Tree Size.

In the field the trees on stock M.IX are very dwarf. Those on stock M.VII are significantly larger than those on M.IX, while trees on stocks M.II,

M.V and M.B, though significantly larger than trees on the two other stocks, do not show any significant difference among themselves. Height, girths at crotch and base of stem, and spread are highly correlated in these investigations.

7. Stock Effects on Vigour.

The stocks could be arranged in the following order as regards vegetative growth: M.B, M.II, M.V>M.VII>M.IX.

8. Stock Effects on Water Contents.

The stocks do not alter the water contents of the wood, bark and leaves portions of the shoots but affect the relative proportions of dry wood, dry bark and dry leaves in the shoots. Shoots on stock M.IX have larger ratios of bark and leaves in shoots as compared with shoots on stock M.B.

9. Stock Effects on Chemical Constituents.

Trees on stock M.IX show a significantly high lime content in wood, bark and leaves in comparison with those on the other stocks.

10. A low potash content was found for stock M.IX, which is interpreted as indicating a low potash requirement.

The order of potash contents for the other stocks is in agreement with their known susceptibility to Leaf Scorch under low potash conditions.

11. Phosphoric acid shows a negative and magnesia a positive correlation with vigour. The magnesia content was negatively correlated with the known order of precocity of the rootstocks, the magnesia values for M.IX and M.VII being particularly low.

12. The trees on stock M.IX show an earlier cycle for ash and phosphoric acid.

13. M.IX shows extreme values for ratios of ash constituents when compared with other stocks, thus indicating that the chemical composition of the annual shoots on M.IX is different from those of the same variety on the other stocks.

SUMMARY.

1. An investigation is described in which the seasonal cycles of ash and of several ash constituents in the terminal shoot portions of Lane's Prince Albert apple trees on five vegetatively propagated rootstocks, M.II, M.V, M.VII, M.IX and M.B, have been followed.

2. The five different rootstocks were included in order to determine whether their effects on the scion were associated with differences in chemical composition, particularly ash constituents, and with differences in the seasonal cycles of these.

3. Samples of the terminal shoots, consisting of sixty to seventy shoots from eight trees on each stock, were collected at monthly intervals from January 1934 to January 1935. They were always taken between 10.30 a.m. and 11.30 a.m. to avoid diurnal variations and under favourable weather conditions to avoid abnormal moisture fluctuations.

4. For the purpose of analysis the shoots were divided into portions, viz. wood, bark and leaves.

5. The determinations made were mean length of shoots ; total dry matter of shoots, wood, bark and leaves ; ash, lime, magnesia, potash, phosphoric acid and some minor ash constituents, including soda, iron oxide, alumina, manganese oxide and silica in wood, bark and leaves.

6. The chief constituents determined were found to exhibit definite seasonal cycles in all three portions of the shoots. The remainder did not exhibit any definite seasonal cycles in any of the three portions of the shoots.

The results for leaves and bark during the period September to November demonstrated autumnal migration of dry matter and of ash constituents, especially potash and phosphoric acid.

7. The rootstocks affected tree size, ratios of bark, wood and leaves in shoots and the chemical composition of the terminal shoots.

8. The seasonal cycles for ash and phosphoric acid in stock M.IX were about one month earlier than those on the other stocks.

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A FIELD EXPERIMENT ON THE MANURING OF BLACK CURRANTS

By T. WALLACE

Long Ashton Research Station, University of Bristol

INTRODUCTION.

It is generally recognized that heavy manuring, especially with dung and nitrogen, is necessary for the successful growing of black currants, and in good commercial plantations manuring is always at a high level. Generous manurial treatment not only ensures the necessary growth of young vigorous shoots, on which the main proportion of the crop is normally borne, but actual yields are increased and quality is improved.

Present-day practices have been developed almost entirely from the personal experiences of growers, since the number of manurial experiments carried out on black currants in England has been very few.

Four experiments require mention, viz. those at Woburn, Bedfordshire; Hadlow, Kent; Cannington, Somerset; and Perdiswell, Worcestershire (1). At all these centres the great effectiveness of dung was shown, and at Hadlow, Cannington and Perdiswell the importance of potash in artificials was demonstrated. At Cannington and Perdiswell nitrogen was also shown to be very beneficial under conditions where it proved injurious to gooseberries. At the former centre omission of phosphorus was without effect on growth or yields.

Results of experiments on the Continent have been very similar to those in England, and it has been shown, in particular, that black currants are more resistant than gooseberries to potash deficiency and to injury from chlorides in fertilizers.

The experiment reported in the present paper forms one of a series which have been laid down on the permanent fertilizer plots at Long Ashton Research Station, in which the effects of dung, complete artificials and the omission of nitrogen, phosphate and potash, respectively, from complete artificials are being compared. It was begun in December 1927 and is still in progress.

The results now reported cover the period 1927-1937. They show that generous manuring has resulted in increased yields, dung being particularly effective, and that nitrogen, phosphate and potash are all of importance in the complete inorganic fertilizer used.

EXPERIMENTAL.

Site and Soil.

The site utilized for the experiment is practically level, and is slightly low-lying and liable to be affected by late spring frosts.

The soil is classified as belonging to Series No. 6 of the Research Station Soils (2), a general description of the profile being as follows:—

Horizon 1. 5 in. Blackish-brown, fine sandy light loam (La). Stoneless, structureless, with bleached sand grains. Calcareous from added material.

,, 2. 12 in. Reddish-brown, tinged with grey, fine sandy loam. Stoneless, structureless. Calcareous (added material).

,, 3. 7 in. Purplish-red, fine sandy loam. Stoneless, occasional small black concretions. Non-calcareous.

,, 4. 12 in. +. Purplish-red, with green flecks, fine sandy, silty heavy loam (Lb).

Drainage is free throughout the depth of the profile. The mechanical analyses of the two surface horizons—Nos. 1 and 2—are as follows:

Table I.

	Horizon 1. %	Horizon 2. %
Stones in Sample	Nil.	Nil.
Coarse Sand	6·45	4·48
Fine Sand	57·06	59·01
Silt	16·05	16·00
Clay	13·70	17·05
Moisture	1·84	1·04
Carbonate of Lime	4·34	<1
Loss by Solution	1·86	1·46
Difference	1·30	1·00
Loss on Ignition	9·34	2·84

In 1928, at the beginning of the experiment, samples of surface and subsoil at 0 to 9 in. and 9 to 18 in., respectively, were taken for determination of the usual chemical data. The results appear in Table XII.

The chemical data show that total nitrogen was high in the surface soil and fairly high in the subsoil; available potash and phosphoric acid were low and carbonate of lime was abundant in both surface and subsoil.

The area was broken up from grass in 1924 after having been used for hay and pasture purposes for a period of approximately sixty years, before which it had been used as a market garden. This latter fact doubtless accounts for the high lime content of the soil and mainly for the high content of organic matter and nitrogen present in the surface soil, although the grass history would also tend to the accumulation of the two latter constituents.

PLOT LAY-OUT AND MATERIAL.

The area containing the plots forms a rectangle 60 yards × 42 yards and is divided into 18 plots, each 14 yards × 10 yards and arranged in three rows.

It is completely planted with black currants, variety Baldwin, at 6 ft. square, there being twenty-four experimental plants on each plot. The plots are separated from one another by buffer rows. The bushes were two years old when planted and were cut to the ground after planting so as to be grown as stools.

MANURIAL TREATMENTS.

There are six experimental treatments, each in triplicate, the details of which are given below. The various treatments are repeated in three blocks, each block comprising a single row of plots, so as to allow of statistical treatment of the data.

Treatment A. No manure.
,, *B.* Farmyard manure at 10 tons per acre annually.
,, *C.* Complete artificials annually, consisting of nitrate of soda 4 cwt., superphosphate 3 cwt. and sulphate of potash 3 cwt. per acre.
,, *D.* As C omitting nitrate of soda.
,, *E.* As C omitting superphosphate.
,, *F.* As C omitting sulphate of potash.

Both the farmyard manure and the artificials have been applied each year during late February or early March. They have been distributed evenly over the whole areas of the respective plots and the manure has not been specially turned into the surface soil but has merely been worked in by the routine cultivations.

MANAGEMENT.

Normal commercial cultural methods have been followed. In the earlier years winter ploughing was done, but later the bushes became too large to allow room for this. Summer cultivation consisted mainly of harrowing and hand-hoeing.

As already stated, the bushes were cut to the ground after planting and in later years pruning consisted in cutting out the greater portion of the old shoots, up to one-third of the bush being removed on each occasion.

The annual routine spraying programme was as follows: a winter wash, usually a standard tar oil at 5-7½ per cent.; lime sulphur 1 in 12 in spring against Big Bud; and Bordeaux mixture 2:4:50 immediately after picking the crop, to control the Leaf Spot fungus, *Pseudopeziza Ribis*, which was very prevalent throughout the experiment.

RESULTS AND DISCUSSION.

Data have been collected each year relating to general growth characters, weights of pruning wood removed, Leaf Scorch, incidence and effects of *Pseudopeziza* on defoliation and cropping. All quantitative records were made on an individual bush basis and were supplemented by detailed field notes.

During the course of the experiment, it became necessary to discard certain bushes from the records, mainly due to Reversion disease. On one plot (A3) thirteen bushes became infected with the Honey fungus (*Armillaria mellea*), presumably from the roots of an old tree which had previously grown on the site, and had to be grubbed. Two bushes were also discarded as "rogues".

Reverted bushes, when removed, were always replaced by new ones to keep the plots full, but refills were not taken into account in the records.

TABLE II.

Showing the Numbers of Bushes discarded from the Records.

Treatments.	A.	B.	C.	D.	E.	F.
Block 1	2	1	0	1	0	1
Block 2	3	3	3	4	5	4
Block 3	15	0	0	3	0	1

1. GENERAL GROWTH CHARACTERS.

In making the field observations, special attention was given to the following points in relation to the manurial treatments: order of coming into blossom and leaf; vigour of shoots; foliage characters, such as amounts, leaf size and tinting; time of defoliation.

At the outset of the experiment, it was perceived that potash deficiency would be of primary importance, since Leaf Scorch appeared to a greater or lesser degree on all the plots in 1928, and was specially marked on the "no manure" and "omit potash" plots. From the first season, this deficiency led to restriction of growth and to slight chlorosis and scorching of the foliage. The problem is fully discussed later in the section on Leaf Scorch. The results throughout the experiment were also greatly influenced by the presence of *Pseudopeziza Ribis*, the attacks of which were influenced by the manurial treatments. This subject is also dealt with fully below, but it may be mentioned here that the fungus determined the time of defoliation each year and often masked growth characters from June onwards.

The manurial treatments did not seem to affect the blossoming dates or the times of coming into leaf, although the young foliage always appeared more vigorous and larger on the plots receiving dung and complete artificials.

Vigour throughout the experiment was generally good and there is no doubt that with appropriate manurial treatment the soil in question will grow excellent crops of black currants.

The growth on the farmyard manure plots was particularly outstanding for vigour, and, especially in the later years, might be described as luxuriant. The second point of note was the restricted shoot growth on the "no manure" and "omit potash" plots, conditions in these two series appearing similar.

The bushes receiving complete artificials were vigorous, but growth was obviously behind that of the farmyard manure plots. On the plots receiving "omit nitrogen" and "omit phosphate" treatments, growth often looked as good as on the complete artificials plots, and there was some variation in condition among the replicates under these treatments; but there were times, especially towards the end of the period under review, when the bushes under these treatments seemed definitely behind those on the complete artificials plots.

Some notes abstracted from the field book for 8/7/32 and 3/8/37 and tabulated below will serve to illustrate the vigour under the different treatments at an early and a late date in the experiment.

TABLE III.

Vigour Records.

Plot ..	1.	2.	3.
8/7/32 Treatment			
A.	Fairly good. Some stunting.	Good. One or two bushes somewhat stunted.	Variable, but generally medium. Some stunting.
B.	Very vigorous.	Very vigorous.	Very vigorous.
C.	Good.	Vigorous.	Good.
D.	Very vigorous.	Good.	Fairly good.
E.	Very vigorous.	Fairly good.	Fairly good.
F.	Fairly good. Some stunting.	Good. Few bushes slightly restricted.	Medium. Fair amount of stunting.
3/8/37			
A.	Medium to poor.	Fairly good.	Medium.
B.	Very vigorous.	Very vigorous.	Very vigorous.
C.	Vigorous.	Vigorous.	Good.
D.	Good.	Medium.	Medium.
E.	Fairly good.	Medium.	Good.
F.	Medium.	Good.	Medium.

The outstanding feature of the foliage characters was the Leaf Scorch symptoms on the "no manure" and "omit potash" plots. These were in evidence each season, generally from June onwards. The brown marginal scorching was usually accompanied by chlorosis between the veins, beginning from the marginal areas and progressing towards the midrib. The intensity of the scorch symptoms varied considerably from season to season, mainly due to the masking effects of *Pseudopeziza*.

No other feature of the foliage has been notable, but it may be mentioned that on a few occasions the leaves on the "omit nitrogen" plots, on plots D2 and D3, appeared somewhat pale, whilst in 1935, from August onwards, the bushes on the "omit phosphate" plots all showed a distinct yellowing of the foliage and became defoliated prematurely.

It was impossible to ascertain the direct effect of the manurial treatments on time of defoliation owing to the complicating factor of *Pseudopeziza* attack, which was responsible for defoliation each season, and the incidence of which was influenced by the manurial treatments, intensity being decreased by potash deficiency and increased by nitrogen or phosphate omission (see below).

Leaf Scorch.

It has been stated earlier that Leaf Scorch was present on all plots during the first growing season (1928) and was most marked on the "no manure" and "omit potash" plots, even at that early date. The detailed records show that the trouble had practically disappeared from all plots receiving potash or farmyard manure in 1930 and no case was noted on these plots from 1932 onward.

On the other hand, from the latter date, practically every bush on plots not receiving potash showed scorching symptoms each season, although in certain years, as in 1937, the intensity on many bushes was extremely slight.

Records of the numbers of bushes showing Scorch in 1929 and 1932 are given below in Table IV.

The data for Leaf Scorch show clearly that potash deficiency was the determining factor in this problem.

It may also be noted that apples and gooseberries, in a similar manurial experiment on an adjoining plot where soil conditions are similar, have failed entirely to make any healthy growth since planting in 1926 where potash has not been given and have been total failures. The greater resistance of the black currant than these two fruits to potash deficiency conditions was thus again demonstrated.

TABLE IV.

Showing the Numbers of Scorched Bushes per Plot 5/8/29 and 1/9/32.

Plot	1.	2.	3.	Totals scorched of 72 bushes.
5/8/29				
Treatment A.	19	11	11	41
,, B.	1	5	8	14
,, C.	4	4	14	22
,, D.	6	10	16	32
,, E.	7	6	2	15
,, F.	21	16	22	59
1/9/32				
Treatment A.	24	23	18	65
,, B.	0	0	0	0
,, C.	0	0	0	0
,, D.	0	0	0	0
,, E.	0	0	0	0
,, F.	24	22	23	69

LEAF SPOT (*Pseudopeziza Ribis*).

This disease was present on the plots in every season and produced marked effects on cropping and defoliation. Observations in the field and examination of the cropping data suggest that the disease has played an important part in determining the order of yields produced under the different manurial treatments.

The critical point seems to be that the intensity of the disease was increased by potash manuring and decreased by either nitrogenous or phosphatic manuring. The net effect of this was that, as the experiment progressed, the " omit potash " plots improved in comparison with the " omit nitrogen " and " omit phosphate " plots, which lost ground because of the severity of the attacks on them. Again, in the earlier stages, the " omit potash " and " no manure " plots stood out as similar from the point of view of the incidence of Leaf Spot, presumably because of the primary deficiency of potash ; but in the later

TABLE V.

Showing the Relation between Manurial Treatment and the Incidence of Leaf Spot.

Percentage Foliage Retained (Order of Retention shown in brackets).

Treatment.	27/10/32	27/9/34	29/10/36	9/8/37
A.	41 (2)	63 (2)	24 (3)	66 (3)
B.	36 (3)	58 (4)	29 (2)	76 (2)
C.	34 (4)	58 (5)	24 (3)	56 (4)
D.	33 (5)	61 (3)	22 (5)	52 (5)
E.	27 (6)	52 (6)	22 (5)	47 (6)
F.	56 (1)	67 (1)	40 (1)	72 (1)

years the "no manure" plots appeared to be losing their relative immunity, possibly because deficiencies of nitrogen and phosphate became more acute.

The outstanding point to be observed as a result of the differential resistance was the difference in the retention of foliage in autumn on the various plots. Quantitative data relating to this point were obtained in four seasons—1932, 1934, 1936, 1937—and are summarized in Table V.

The relatively low susceptibility under treatments F (omit potash) and A (no manure) and the high susceptibility under D (omit nitrogen) and E (omit phosphate)—especially E—are clearly evident throughout the Table, whilst a further point of note is the increasing resistance under treatment B (farmyard manure) in the later years. It is possible that the latter effect is due to a high nitrogen status in the plants, but this point requires chemical confirmation (see Soil Data, Table XII).

The primary infection of the bushes in 1928 appeared to come from an older block of black currants, situated to the east of the manurial plots. The initial attack was practically confined to the east half of the plots and, although the infection became general over the area in the next season or two, the effects of the first year's infection were visible for several seasons and were clearly evident in the crop records as late as 1931, a heavy cropping year, as the following comparative figures show.

TABLE VI.

Showing the Effects of Pseudopeziza *on Cropping—Season* 1931.

(*Kilos per Plot.*)

Pseudopeziza Severe.			*Pseudopeziza* Slight.		
A1 19·67	F1 19·56	C1 27·81	B1 34·14	E1 31·84	D1 35·38
E2 18·59	B2 28·57	D2 23·10	A2 27·31	F2 28·65	C2 32·37
D3 19·24	C3 22·00	F3 16·63	E3 26·17	B3 32·93	A3 24·63

It should be noted in connection with Leaf Spot that it was severe each season in spite of annual spraying with Bordeaux mixture (2 : 4 : 50) immediately after removal of the crop.

PRUNING WEIGHTS.

Pruning weights, per bush, are available for each season since planting. These may be expected to reflect in some measure, though not fully, the effects of the treatments on vigour, and to show to what extent extra labour may be required for larger bushes.

Three statistical analyses have been made from the data with the following objects in view:—

a. Data at planting, to determine the degree of uniformity of the original material.

b. Data for ten seasons (1928-1937), to determine differences produced over the whole experimental period.

c. Data for the last three seasons (1935-1937), to see whether in the later stages of the experiment differences were increasing or changing in any other way.

The data and results of the statistical analyses made by the method of variance are given in Tables VII to IX.

TABLE VII.

a. Pruning Data at Planting—Mean Weights per Bush (gm.).

Blocks.	Treatments.						Totals for Blocks.
	No Manure.	F.Y.M.	Complete Artificials.	Omit N.	Omit P.	Omit K.	
1	159	169	162	160	140	165	955
2	172	130	163	184	169	158	976
3	167	191	160	187	158	146	1006
Totals for Treatments	498	490	485	531	467	469	2940

General Mean 163·3

b. Analysis of Variance.

	Degrees of Freedom.	Sum of Squares.	Mean Square.	Log e.	z	Remarks.
Blocks	2	345	173	5·1533	—	Not significant.
Treatments	5	1011	202	5·3083	—	Not significant.
Error	10	2706	271	5·6021		

The data in Table VII show that the bushes at planting, as measured by shoot weights pruned away in cutting back to the stools, were very uniform in

size over the plots, and it can be concluded that the material used was satisfactory in this respect.

In Table VIII it is shown that, when the ten-year period, over which prunings were taken, is considered as a unit, none of the treatments significantly increased the pruning weights. The orders of the weights shown in Table VIIIa, however, are of interest, since they are identical with those given in Table IXa, where the treatments are beginning to show significant effects.

TABLE VIII.

a. Pruning Data for Ten Seasons (1928-1937)—*Mean Weights per Bush* (*kilos*).

Blocks.	Treatments.						
	No Manure.	F.Y.M.	Complete Artificials.	Omit N.	Omit P.	Omit K.	Totals for Blocks.
1	7·17	13·36	9·97	12·70	9·71	8·36	61·27
2	9·62	11·99	12·67	7·72	8·23	10·02	60·25
3	7·94	14·79	7·99	7·67	9·57	6·88	54·84
Totals for Treatments	24·73	40·14	30·63	28·09	27·51	25·26	176·36
						General Mean	9·80
Treatments as % of "No Manure".	100	162	124	114	111	102	

b. Analysis of Variance.

	Degrees of Freedom.	Sum of Squares.	Mean Square.	Log e.	z	Value of z for 5% Point.	Remarks.
Blocks	2	3·5888	1·7944	0·5845	—		
Treatments	5	53·3071	10·6614	2·3666	0·5227	0·6009	Not significant.
Error	10	37·4803	3·7480	1·3212			
Totals	17	94·3762					

Table IXc shows that, over the latest three-year period, the farmyard manure treatment produced an increase significant above the 1 per cent. point and that no other treatment significantly affected the pruning weights, although the value for complete artificials was nearing the 5 per cent. significant point and all treatments showed higher percentages over the "no manure" plots

than for the ten-year data. This latter fact suggests that other significant increases will be shown in future years.

TABLE IX.

a. Pruning Data for Three Seasons (1935-1937)— Mean Weights per Bush (kilos).

Blocks.	Treatments. No Manure.	F.Y.M.	Complete Artificials.	Omit N.	Omit P.	Omit K.	Totals for Blocks.
1	2·49	6·35	4·69	5·49	4·16	3·33	26·42
2	3·77	5·98	5·40	3·36	3·77	4·20	26·48
3	3·17	7·60	3·68	3·59	4·33	2·80	25·17
Totals for Blocks	9·34	19·93	13·77	12·44	12·26	10·33	78·07
						General Mean	4·34
Treatments as % of "No Manure"	100	213	148	133	132	111	

b. Analysis of Variance.

	Degrees of Freedom.	Sum of Squares.	Mean Square.	Log e.	z	Value z for 5% and 1% Points.	Remarks.
Blocks	2	0·1824	0·0912	$\bar{3}$·6053	—		
Treatments	5	23·3343	4·6669	1·5405	0·9079	0·6009 0·8646	Significant.
Error	10	7·5937	0·7594	$\bar{1}$·7247			
Totals	17	31·1104					

c. Showing Significant Differences due to Treatments— Mean Weights per Bush (kilos).

No Manure.	F.Y.M.	Complete Artificials.	Omit N.	Omit P.	Omit K.	Remarks.
3·11	6·64	4·59	4·15	4·09	3·44	S.E.=0·503
	Significant to 1%	Not significant.	Not significant.	Not significant.	Not significant.	Significant for 5% point = 1·975 Significant for 1% point = 3·239

Crop Yields and Quality.

Nine consecutive crops were recorded, for the seasons 1929 to 1937 inclusive but, unfortunately, only three of these were satisfactorily heavy, two at an early stage in the cropping history of the bushes, 1930 and 1931, and the other in the last season, 1937.

The bushes blossomed heavily each year and the light crops are to be attributed mainly to frost injury, which was severe in 1929, 1933, 1935 and 1936, and to injury resulting from the lime sulphur spray which was applied each season with the exception of 1937. The effects of *Pseudopeziza* on yields have previously been mentioned (Table VI). The crop for 1937, which was very heavy and free from frost effects and complications due to lime sulphur spraying, doubtless gives the truest picture of the potential cropping powers of the bushes under the respective treatments.

The data for crop yields for the nine seasons, 1929-1937 inclusive, and for 1937 alone, together with the relevant statistical analyses, are given in Tables X and XI.

The statistical analyses of the data in Tables X and XI show that only the two treatments, farmyard manure and complete artificials, have produced significant increases in yields over the "no manure" plots, the farmyard manure to the highly significant 1 per cent. point (100 to 1 odds) and the complete artificials to the 5 per cent. point (20 to 1 odds). The results as regards significance are identical in the two cases examined, i.e. over the nine-year period and for 1937 only.

The cropping results differ from those for pruning weights in that complete artificials produced a significant increase for the former. When the data for apparent percentage increases due to the treatments over the "no manure" treatment are examined in the Tables for pruning and crop weights (Tables VIIIa, IXa, Xa and XIa), it will also be seen that the percentage increases shown for crops are generally higher than those for pruning weights.

The orders of the plots for increases in crop yields and pruning weights are, moreover, the same throughout, viz. highest to lowest: farmyard manure, complete artificials, omit N, omit P, omit K.

A further point shown in the yields data in Tables X and XI in comparing the percentage increases is that, whilst in the treatments "omit nitrogen" and "omit phosphate", respectively, the percentages relative to the "no manure" treatment are practically identical, in "omit potash" the value for 1937 only —124—is appreciably higher than for the nine-year period—104. In this connection it has already been pointed out that the "omit potash" plots may be improving relative to those not receiving nitrogen or phosphate, due to the greater severity of *Pseudopeziza* attacks on the latter. There is also a

suggestion that the "omit potash" plots are improving in position relative to those receiving the complete fertilizer, since the latter show significantly higher yields over the nine seasons' period whilst the difference is well below the significance point for the 1937 crop.

TABLE X.

a. Crop Yields for Nine Seasons (1929-1937)—
Total Mean Weights per Bush (*kilos*).

Blocks.	Treatments.						
	No Manure.	F.Y.M.	Complete Artificials.	Omit N.	Omit P.	Omit K.	Totals for Blocks.
1	5·89	13·72	11·10	13·30	9·79	7·26	61·06
2	7·67	12·56	13·87	8·57	8·51	8·33	59·51
3	7·86	15·27	9·70	8·55	9·37	6·67	57·42
Totals for Blocks	21·42	41·55	34·67	30·42	27·67	22·26	177·99
						General Mean	9·89
Treatments as % of "No Manure"	100	194	162	142	129	104	

b. Analysis of Variance.

	Degrees of Freedom.	Sum of Squares.	Mean Square.	Log e.	z	Value z for 5% and 1% Points.	Remarks.
Blocks	2	1·1122	0·5561	$\bar{1}$·4132	—		
Treatments	5	97·8891	19·5778	2·9745	0·9184	0·6009 0·8646	Significant.
Error	10	31·2005	3·1201	1·1378			
Totals	17	130·2018					

c. Showing Significant Differences due to Treatments—
Total Mean Weights per Bush (*kilos*).

No Manure.	F.Y.M.	Complete Artificials.	Omit N.	Omit P.	Omit K.	Remarks.
7·14	13·85 Significant to 1%	11·56 Significant to 5%	10·14 Not significant.	9·22 Not significant.	7·42 Not significant.	S.E. = 1·02 Significant for 5% point = 4·00 Significant for 1% point = 6·63

TABLE XI.

a. Crop Yields for Season 1937—Total Mean Weights per Bush (kilos).

Blocks.	Treatments.						
	No Manure.	F.Y.M.	Complete Artificials.	Omit N.	Omit P.	Omit K.	Totals for Blocks.
1 2 3	1·134 1·657 1·728	3·935 3·443 4·406	2·944 2·919 2·278	2·704 2·008 1·564	2·344 1·650 1·929	1·789 2·075 1·748	14·850 13·752 13·653
Totals for Blocks	4·519	11·784	8·141	6·276	5·923	5·612	42·255
						General Mean	2·348
Treatments as % of "No Manure"	100	261	180	139	131	124	

b. Analysis of Variance.

	Degrees of Freedom.	Sum of Squares.	Mean Square.	Log e.	z	Value z for 5% and 1% Points.	Remarks.
Blocks	2	0·1471	0·0736	$\bar{3}$·3909	—		
Treatments	5	11·3146	2·2629	0·8167	1·2714	0·6009 0·8646	Significant.
Error	10	1·7799	0·1780	$\bar{2}$·2740			
Totals	17	13·2416					

c. Showing Significant Differences due to Treatments—
Total Mean Weights per Bush (kilos).

No Manure.	F.Y.M.	Complete Artificials.	Omit N.	Omit P.	Omit K.	Remarks.
1·506	3·928 Significant to 1%	2·714 Significant to 5%	2·092 Not significant.	1·974 Not significant.	1·871 Not significant.	S.E. = 0·2435 Significant for 5% point = 0·956 Significant for 1% point = 3·239

A possible explanation of these points is that potash deficiency decreases susceptibility to *Pseudopeziza* attack whilst nitrogen and phosphorus deficiency increase it. Following this idea, susceptibility will continue to increase on "omit nitrogen" and "omit phosphorus" plots due to deficiencies of these elements, whilst with complete artificials, susceptibility will be decreased by

high nitrogen and high phosphate and increased by high potash. That high potash may be of more importance in increasing susceptibility than is high nitrogen in increasing resistance has been indicated in an experiment carried out by the writer in a commercial plantation (results unpublished), where the susceptibility of bushes initially low in both nitrogen and potash has been greatly increased by manuring with nitro-chalk at 4 cwt. and sulphate of potash at 3 cwt. per acre for three seasons.

Detailed examinations of quality were made, immediately after picking, on bulks of fruit from the various plots on two occasions, July 18th, 1935, and July 7th, 1937, the former a light cropping year and the latter a heavy cropping one.

The salient points were as follows, on the first examination (18/7/35):—

Size. Large for farmyard manure and complete artificials ; variable for "no manure", "omit K", "omit P", "omit N"—especially the two former.

Ripeness. Uneven for "no manure" and "omit K", and fair proportion of unripened fruit ; "omit N", tendency to over-ripeness.

Flavour. Full for farmyard manure and complete artificials ; "omit N", tendency to be sweet ; "omit P", tendency to be acid ; "no manure" and "omit K", variable, ripe fruits tendency to be sweet.

For the second examination (7/7/37) the following Table gives details:—

Plot ..	1.	2.	3.
A.	Small, many red, striggy.	As A1.	As A1.
B.	Size good, very slightly red.	As B1.	Large, few red and green.
C.	Large, few red and green.	As C1.	As C1.
D.	Size good.	Size good. Somewhat striggy.	Size good.
E.	Size large.	Size good.	As E2.
F.	Size variable, many red, striggy.	As F1.	As F1.

The outstanding point which emerged was the variability and delayed ripening on the "no manure" and "omit K" plots. There was a tendency to earlier ripening on the "omit N" plots in 1935.

SOIL DATA.

A point of considerable importance in connection with cultural and manurial systems in fruit growing is the ultimate effect of these on soil fertility when fruit is grown for a considerable period on any given site. This is specially important with tree fruits, where cases are often observed in which

soils, particularly under arable culture, eventually show considerable deterioration and the trees fall off in vigour and may even die. When such areas are replanted with young tree or bush fruits failures are often experienced. The condition is sometimes referred to as soil "fatigue" (German "Müdigkeit"). Since an excellent opportunity presents itself for studying this problem on the Long Ashton permanent fertilizer plots, a beginning has been made by examining certain chemical data in the experiment under review. It is not proposed at this stage to deal exhaustively with the subject but merely to present some summarized results of interest, to indicate the apparent course of events on the plots receiving the treatments "no manure", "farmyard manure" and "complete artificials".

The data to be discussed are given in Table XII and refer to composite samples of surface soil and subsoil, taken by sampling over the whole of the area at the beginning of the experiment, and to samples taken from each plot of the three treatments shown in October 1937, at the end of the period under review.

In considering the data in Table XII the following points should be noted:—

Moisture. The relative amounts of this constituent are probably mainly determined by the amounts and character of the organic matter present. Considerable falls in values are shown in 1937 for all subsoils and for "no manure" and "complete artificials" in the surface soils.

Loss on Ignition. This is a very approximate measure of organic matter content and here it is seen that considerable losses in both surface soils and subsoils have resulted from all treatments. "Complete artificials" is associated with the greatest apparent losses.

Total Nitrogen. The original values for both surface soil and subsoil tended to be high. The lowered values in all treatments, both in surface soils and subsoils, are very striking. Farmyard manure treatment again shows the highest values for 1937. This may be of importance in connection with both yields and relative resistance to *Pseudopeziza* in recent years.

Available Potash. The initial values for this constituent were low both in surface and subsoil. All treatments show higher values in the surface soil than for the original sampling, the value for complete artificials being notably higher than for farmyard manure. The increases in the subsoil from the treatments are small and suggest considerable fixation of potash by the surface soil.

Phosphoric Acid. As for potash, the values prior to the experiment were low both in surface and subsoil. All 1937 values for the surface soil are higher than for the initial samples, and the rises for farmyard manure and complete artificials are considerable, the former showing a higher value than

TABLE XII.

Chemical Data for Soils—Mean Percentage Values for Composite Sample, February 1928, and for Three Treatments, October 1937.
(Results on air-dried samples.)

Chemical Constituent.	Composite Sample, 1928.		No Manure.		Farmyard Manure.		Complete Artificials.	
	Surface Soil.	Subsoil.	Surface Soil.	Subsoil.	Surface Soil.	Subsoil.	Surface Soil.	Subsoil.
Moisture	3·76	2·73	2·10	1·24	3·28	1·45	2·29	1·63
Loss on Ignition	10·71	4·23	7·59	3·06	7·54	3·30	6·89	2·74
Total Nitrogen	0·330	0·154	0·209	0·077	0·290	0·084	0·205	0·077
Available Potash (K_2O)	0·0057	0·0053	0·0077	0·0050	0·0117	0·0069	0·0179	0·0068
Available Phosphoric Acid (P_2O_5) ..	0·0074	0·0072	0·0087	0·0055	0·0588	0·0078	0·0304	0·0070
Carbonate of Lime* ($CaCO_3$)	5·0	>3·0	5·0	1·0	5·0	1·0	5·0	1·0

* Values for this constituent by approximate tests only.

the latter, which is the opposite to the result for potash. In the subsoils, there is no appreciable change from 1928, and the values again suggest that so far the whole of the added phosphate has been fixed in the surface soils of the plots.

In connection with the fixation of potash and phosphate in the surface soils, it should be noted that the texture is not "heavy", being only that of a light, fine sandy loam.

Carbonate of Lime. So far, only approximate tests have been made and these have not indicated any appreciable change in lime content during the experiment.

CONCLUSIONS.

1. At the beginning of the experiment potash deficiency was the chief limiting factor to growth. Symptoms of this deficiency were completely overcome after three or four seasons by potash and farmyard manure treatments. Apart from stunting, associated with potash deficiency, growth was generally good, being particularly vigorous on farmyard manure plots, somewhat less vigorous under complete artificials treatment and inclined to fall away in later seasons where "omit nitrogen" and "omit phosphate" treatments were given. "Omit potash" and "no manure" treatments resulted in moderate growth and caused some stunting of shoots, marginal Leaf Scorch and slight chlorosis of foliage throughout the experiment. The different treatments did not affect time of blossoming or the time of breaking into leaf. Leaf symptoms were often masked by attacks of *Pseudopeziza Ribis,* and this fungus also determined the time of defoliation each season.

2. Leaf Spot, caused by *Pseudopeziza Ribis,* was severe each season throughout the experiment. The initial infection was confined to the east half of the area and seriously affected crop yields in that section until 1931.

As judged by data relating to defoliation, susceptibility to *Pseudopeziza* attacks was decreased by potash deficiency and increased by deficiencies of nitrogen or phosphate. Farmyard manure treatment also tended towards increased resistance. The effects of the manurial treatments on cropping in the later seasons of the experiment were possibly significantly modified by these differential susceptibilities towards the fungus. Spraying with Bordeaux mixture, 2:4:50, each season, immediately after picking the crop, did not prevent very severe attacks of *Pseudopeziza.*

3. Pruning data obtained immediately after planting showed that the material used in the experiment was very uniform.

Although apparently substantial increases were recorded for pruning weights over the ten seasons of the experiment, none of these was statistically significant. Larger apparent increases were recorded for the last three seasons

of the experiment than for the complete period and, in the former, the increase due to farmyard manure was substantially significant to the 1 per cent. point (100 to 1 odds), whilst that shown by complete artificials was almost significant to the 5 per cent. point (20 to 1 odds).

The orders of the pruning weights on both occasions were identical and agreed with the field observations on vigour.

4. Significant increases in crop yields were obtained for total crops over nine picking seasons and for the heavy cropping season of 1937 from the treatments farmyard manure (1 per cent. point) and complete artificials (5 per cent. point). Significant increases did not occur where nitrogen, phosphate or potash was omitted from the complete fertilizer, and all three elements appear essential for increased crops.

Fruit quality was affected by the manurial treatments. Fruit from "no manure" and "omit potash" plots was variable in size, ripened unevenly and strigs were greatly in evidence.

The relative orders for pruning and cropping weights on the "omit nitrogen", "omit phosphate" and "omit potash" plots indicate that potash has been the chief limiting factor to date, and that the effects of the other two deficiencies have been similar to each other.

5. On the plots receiving the treatments "no manure", "farmyard manure" and "complete artificials", significant effects occurred during the experiment in regard to certain chemical constituents of the soil.

Moisture (in air-dried sample), loss on ignition and total nitrogen were all decreased, both in surface soils and subsoils, the decreases being smallest on the farmyard manure plots.

Available potash and phosphoric acid showed increases in all cases in surface soils, potash being highest in the "complete artificials" and phosphoric acid in the farmyard manure plots. Increases in the subsoils for both constituents were relatively small.

The results for potash and phosphoric acid suggest that considerable proportions of these materials were fixed by the surface soils.

The contents of free carbonate of lime in the soils did not show appreciable change during the course of the experiment.

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The statistical analyses of pruning weights and yields were carried out by Dr. V. G. Vaidya.

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SUMMARY.

1. A manurial experiment with black currants, variety Baldwin, carried out on the fertilizer plots at the Research Station, Long Ashton, over the period 1927-1937, is described.

2. The soil is a light, fine sandy loam, classified as belonging to Series No. 6 of the Research Station's Soils. Data relating to profile characters and to the mechanical composition of the upper horizon are given.

3. The manurial treatments under comparison were no manure, farmyard manure, complete artificials, and complete artificials omitting N, P and K respectively. They were in triplicate and distributed in randomized blocks.

4. Data were obtained relating to general growth characters, Leaf Scorch, incidence and effects of *Pseudopeziza Ribis*, pruning weights, crop yields and quality, and soil constituents as affected by the plot treatments.

5. Potash was the primary deficiency in the area, but later both nitrogen and phosphorus deficiencies showed as limiting factors to growth.

6. Severe attacks of *Pseudopeziza* occurred each season and exerted significant effects on defoliation and crop yields. Potash deficiency appeared to decrease susceptibility to the fungus, and deficiencies of nitrogen and phosphorus to increase it.

7. Pruning weights were increased to a significant extent by farmyard manure treatment only and only in the later years of the experiment.

8. Yields were significantly increased by farmyard manure and complete artificials, and the results with the former suggest that the common practice of using this material is justified. Berry quality was poor where potash was deficient, size being variable, ripening uneven and the bunches striggy.

9. Soil data for samples taken on the "no manure", "farmyard manure" and "complete artificials" plots in 1937 showed that all these treatments had caused decreases in moisture in air-dried sample, loss on ignition and total nitrogen in surface soils and subsoils.

Available potash and phosphoric acid were both increased appreciably in the surface soils by farmyard manure and complete artificials, but the increases in the subsoils were very small, suggesting fixation of the constituents in the surface soils. The farmyard manure plots showed higher amounts of P_2O_5 and lower amounts of K_2O in the surface soils than the complete artificials plots.

Carbonate of lime content was not appreciably affected during the experiment.

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A FIELD EXPERIMENT ON THE MANURING OF STRAWBERRIES

By T. WALLACE and V. G. VAIDYA
Long Ashton Research Station, University of Bristol

INTRODUCTION.

The strawberry plant is generally regarded by horticulturists in this country as requiring exceptionally favourable cultural conditions and, in the past, was grown very largely by small growers under conditions of high cultivation and generous manuring, hand labour and the liberal use of dung being regarded as essentials to success.

It is only too well known that, since 1921, strawberry production has been extremely difficult and, indeed, on some holdings and even throughout some districts, strawberry growing has been seriously curtailed or has even died out altogether. Failures have often been associated with specific pests and diseases, and some of these have come to be regarded as responsible for the more serious troubles.

There are still some growers, however, who hold the opinion that many of the diseased conditions have resulted from the changed conditions of culture and manuring which have been forced on the industry since the war and, in particular, from the shortage of dung which is general in the majority of districts.

In view of the conditions and ideas prevailing in 1923, when the serious nature of the problems facing the industry, through wholesale failures of plants, was first becoming recognized, two manurial experiments were begun, at the Botley Strawberry Station, Hants, and at Long Ashton respectively, in which identical manurial schemes were adopted in an endeavour to throw some light on the nutritional aspects of the problems.

The experiments at both centres were planned with the following objects in view:—

a. To determine whether good crops of strawberries could still be grown when liberally supplied with dung.

b. To see how the results of other practicable manurial systems compared with those from dung.

c. To ascertain the effects of the continuous cropping of land with strawberries under the various manurial treatments.

The last point was of importance in view of the popular opinion that continuous cropping with strawberries led to land becoming strawberry "sick"

and of the fact that it was not possible for the majority of smallholders specializing in strawberries to practise rotational cropping.

In order to carry out the aims of the experiment, an area of land was selected at Long Ashton which, so far as was known, had never previously been used for strawberry culture, and which was only of moderate fertility. It was proposed to crop the area continuously with strawberries over a considerable period of years, new plantings being normally made every third season.

It will be seen from the details of the treatments below that the manurial systems compared included heavy dressings of dung, a light dressing of dung supplemented with artificial fertilizers, bulky and non-bulky "organic" manures, a purely inorganic fertilizer and an organic manure without potash. It was thought that these systems were representative of the main options available to the strawberry grower.

At both Botley and Long Ashton it was planned to make the first planting during the autumn of 1923, but at the latter centre this had to be delayed until the following spring. In both places the experiments have been continued from 1924 to the present time with only minor alterations in the original treatments. The results for the Botley experiment up to the 1937 crop have been published,* and those for the Long Ashton experiment are reported herein.

As will be shown later, the results at the two centres, as regards the effects of the various manures, have been very similar and have demonstrated that the drastic failures in strawberries since the war cannot be attributed to defects in manuring, but rather to certain pests and diseases whose incidence is not affected by manurial practices.

In the present paper the results reported from the manurial treatments relate primarily to vigour of growth and crop yields, but the quality aspect of the crops has received detailed attention during the experiment.

A special report on the quality of the 1931 crops has been published previously in this Journal (4).

HISTORICAL.

Accounts of the main manurial experiments on strawberries previously carried out in this country and abroad have been given in earlier publications by one of us (T.W.) (6, 8), so that it is necessary here only to summarize the salient points.

In England, the main trials have been those of Bedford and Pickering at Woburn, Bedfordshire (1), Dyer and Shrivell at Hadlow, Kent (3), and Turner and Forshaw at Cannington, Somerset (7).

* *Gleed, C. J.* and *Wallace, T.* Strawberry Manurial Experiment, 1923-1937. Botley Fruit Experiment Station, Report of Experiments on Strawberries, 1938, pp. 31-4.

At Woburn, the increases from both dung and artificial fertilizers were very small, averaging only 12 per cent., and dung gave increases of only 8 per cent. over artificials.

The Hadlow experiments, which consisted of five plantings over nineteen years, yielded variable results. In these trials heavy dunging was not superior to light dunging supplemented with artificials, and potash was beneficial in the absence of dung.

At Cannington, potash deficiency proved the most important point, leading to almost total failure of the plants on the "omit potash" plots; complete artificials treatment was the most effective; dung (at the low rate of 5 tons per acre) overcame potash deficiency only partially, and yields suffered accordingly; nitrogen omission was not very important, but phosphate omission led to lowered yields, and crowns of old plants from this treatment when split and planted out later tended to remain moribund.

Results abroad have been very variable. In the U.S.A. superphosphate and nitrogenous fertilizers have occasionally produced increases but potash has generally, if not invariably, proved ineffective (2).

In Germany, the results of Lierke were in the order $K > P > N$ (5).

All who have carried out manurial trials with strawberries are agreed on one point, viz. that the plant is a most difficult one with which to work owing to its ready and large responses to changes in environmental conditions other than manuring.

EXPERIMENTAL.

Site and Soil.

Some details of these were given in the previous paper (4), but for the convenience of readers the chief points are outlined here.

The site is practically level and is fairly open, the main protection being by a windbreak on the west side. The soil belongs to the same series as that of the black currant manurial plots previously reported (9), viz. Series No. 6 of the Long Ashton Research Station Soils. The area, however, is outside the site of the old market garden and, because of this, the surface soil in 1923 was devoid of carbonate of lime and slightly acid, and was not so well supplied with organic matter.

Prior to 1917 the area had been under grass for many years. The turf was ploughed out in 1917 and from then until 1923 the land was utilized for arable crops.

As it is proposed to discuss the soil aspects of the plots in detail in a subsequent paper, it is necessary to give only the following particulars here:—

The profile is similar in general character to that described previously for Series No. 6 (9), except that the surface horizon is less dark in colour, due to

a lower content of organic matter, and in 1923 was devoid of free carbonate of lime ; the texture is slightly heavier than on the black currant plots, varying from a light to a medium fine sandy loam ; and drainage is slower. Values for available potash and phosphoric acid in surface and subsoil on the " no manure " plots in 1932 were as follows:—

	Surface.	*Subsoil.*
Available Potash	0·0126	0·0065
,, Phosphoric Acid ..	0·0227	0·0092

In view of the low lime status of the soil, two dressings of ground limestone were given during the experiment, in 1923 at 2 tons per acre and in 1935 at 1 ton per acre.

Drainage was not always satisfactory during the experiment and on certain occasions, after very wet periods, sections of the plots suffered from wet soil conditions.

PLOT LAYOUT AND PLANTINGS.

The area, which measures approximately 230 ft. × 100 ft., contains twenty-four manurial plots each 34 ft. × 22 ft. 6 in. (i.e. each 1/60 acre approximately). The plots are separated by alleyways, two 3 ft. 6 in. and one 4 ft. 6 in. wide down the length of the area, and five 6 ft. wide across the area, so that each plot forms a kind of bed which is raised slightly above the level of the alleyways to assist surface drainage.

The variety used was Royal Sovereign and in all plantings the plants have been set out in rows 30 in. apart, with spaces of 18 in. between plants in the rows, each plot containing 9 rows and 207 plants.

As regards time of planting, late summer or early autumn (July or August) has been aimed at throughout the experiment, since this enables appreciable crops to be gathered in the " maiden " year ; but such planting has not always been possible, as will be seen from the details given below, due to lateness of runner formation in some seasons, unfavourable planting conditions, etc.

During the period under review, five plantings have been made and the sequence of strawberries has been unbroken with the single exception that a mustard crop was taken in 1935 between the 4th and 5th plantings.

The details of the plantings are as follows:—

1st Planting, April 1924. The plants used were obtained from four sources in the Cheddar area with the object of comparing different strains. Similar numbers of each strain were planted on each plot. It was intended to plant during the previous autumn but the runners came to hand too late for this and had to be over-wintered in a cold frame. The quality of the runners as a

result was only moderate at planting and the stand of plants was also affected by wet conditions following planting.

2nd Planting, July 1926. An excellent stock of plants was procured from a nurseryman for this planting, which was carried out under favourable conditions. The plants made excellent growth in the initial stages after planting.

3rd Planting, August 1929. A specially vigorous strain, propagated at Long Ashton from purchased parent runners, was utilized. Planting conditions were entirely satisfactory and the young plants grew away vigorously.

4th Planting, August 1932. Plants of the same strain as the 3rd planting were used, the runners again being raised at Long Ashton from purchased parents. The plots were subsoiled prior to planting. Favourable planting conditions were followed by a rainy period and some of the plots became very wet.

5th Planting, April 1936. The plants of the previous planting had been ploughed up in May 1935, following a frost which destroyed the blossom. The plots were subsoiled, and a crop of mustard was grown as a green manure crop in June and July of that year. After ploughing in the mustard, a dressing of ground limestone was applied in September and the land fallowed over winter, since runners were not available until too late in the autumn. The plants used were obtained from an outside source. Planting was carried out under wet conditions, and a frosty period after planting caused many casualties which were replaced by runners of the same strain during the following July.

Manurial Treatments.

There were eight manurial treatments in the experiment, each in triplicate and distributed in three randomized blocks.

The original scheme of treatments was as shown in Table I.

Table I.

Manurial Treatments.

Treatment A. *Dung* at 20 tons per acre, to be ploughed in previous to planting. No further manuring to be given during three-year period.

Treatment B. *Dung* at 10 tons per acre, to be ploughed in as in A. *In addition* a complete fertilizer to be given each spring as under :—

Sulphate of Ammonia	to supply 20 lb. N per acre.
Superphosphate	150 lb. Total Phos. (i.e. 75 lb. P_2O_5) per acre.
Sulphate of Potash	50 lb. K_2O per acre.

Treatment C. *Shoddy* (on basis of 5 per cent. Total Nitrogen) at the rate of 2 tons per acre, to be ploughed in as in A. *In addition*, to be given each spring as under :—

Steamed Bone Flour	150 lb. Total Phos. per acre.
Sulphate of Potash	50 lb. K_2O per acre.

Treatment D. "*Complete Organic*" Manure (non-bulky), to be applied each spring as under :—

Dried Blood	40 lb. N per acre.
Steamed Bone Flour	150 lb. Total Phos. per acre.
Sulphate of Potash	50 lb. K_2O per acre.

Treatment E. "*Complete Inorganic*" Manure, to be applied each spring as under :—

Sulphate of Ammonia	40 lb. N per acre.
Superphosphate	150 lb. Total Phos. per acre.
Sulphate of Potash	50 lb. K_2O per acre.

Treatment F. "*Organic Manure*" containing N and P_2O_5, but no Potash, to be given each spring :—

Dried Blood	40 lb. N per acre.
Steamed Bone Flour	150 lb. Total Phos. per acre.

Treatment G. *Dung* at rate of 12 tons per acre, to be ploughed in previous to planting.
Dung at rate of 8 tons per acre, to be spread on the surface in March, following the taking of the first crop.

Treatment H. *Control Plot.* No manure to be given throughout the period of the experiment.

This scheme was followed until the spring of 1936 when the 5th planting was made. At that time the following alterations were made for use in 1936 and subsequent seasons.

1. Rates for nitrogen, phosphate and potash were altered to the following equivalents, *vice* 40 lb. N, 150 lb. Total Phosphate and 50 lb. K_2O per acre :—

Nitrogen	equivalent to	3	cwt.	Nitro-chalk per acre.
Phosphate	,, ,,	4	,,	Superphosphate per acre.
Potash	,, ,,	2	,,	Sulphate of Potash per acre.

2. Nitro-chalk was substituted for Sulphate of Ammonia.

3. The rates for N, P, K in the artificials in Treatment B were at half the rates used in Treatment E. Previously only N had been used at the half rate in E.

The spring applications of fertilizers were made each season during early March, great care being taken to ensure even distribution.

Management.

Cultivation has consisted mainly of hand-hoeing, with occasional digging when wet weather prevented weed control by the former method. Weeds were normally left to rot or dry out *in situ* on the plots, but occasionally, when weather conditions were unfavourable, they were removed or turned under. Only on one or two occasions was horse labour employed when plants were growing on

the plots. Between plantings the plots were ploughed and well harrowed, and on two occasions, in 1932 and 1935, subsoiling was carried out. The object of the hand cultivation was to maintain a satisfactory surface tilth without risk of disturbing the roots. Experience during the experiment has shown that more frequent digging will probably prove advantageous.

The standard of cultivation throughout was always satisfactory.

The plots were "strawed" prior to picking each crop.

Routine spraying was not practised, but a careful look out was always kept for pests and diseases and appropriate control measures promptly taken.

RESULTS AND DISCUSSION.

The records collected throughout the experiment were very detailed. They related to general growth characters, vigour of the plants, incidence of pests and diseases, dying out of plants, crop yields and quality of the fruit.

In recording data concerning growth characters, vigour and dying out of plants, careful examinations were specially made (1) in early spring, (2) just previous to cropping, (3) immediately subsequent to picking and (4) in late autumn, in order to relate the observations to special seasonal conditions. Thus, the early spring observations reflected the over-wintering conditions, and the pre- and post-picking records the effects of the crops on the plants, whilst the nature of late growth in autumn provided a measure of recovery from cropping and of the condition of the plants on entering the winter rest period. The dying out of plants was considerable in some plantings where diseases or unfavourable growing conditions occurred, and quantitative data on this point were collected by recording the number of missing plants on each plot. Vigour was assessed by a system of marks which is discussed later.

General Growth Characters.

The characters mentioned in this section were supplementary to the vigour markings discussed below. They concerned foliage features and types of plants, especially with a view to explaining causes of low vigour.

It was noted in the course of these observations that the best time for assessing differences in nutritional status was shortly after cropping, in July, when the plants were feeling the drain of the recently gathered crops. At this time of year the plants usually showed much purple tinting of the foliage, and this was generally strongly marked on the weaker plants. The only other symptom of note which occurred was marginal leaf scorch, which varied considerably from season to season and was also most pronounced during July. The "no manure" and "omit potash" plots, especially the latter, could

usually be picked out from the others by means of scorching symptoms in this month. In addition, the "no manure" plots tended to show slightly paler green foliage at that time. The only other outstanding point was the comparative luxuriance of the foliage on all plots receiving farmyard manure, and at most times it was possible to locate these plots by casual inspection. The foliage on them also generally showed distinct purpling in July.

Causes determining low vigour which were noted were: soil wetness, which caused dwarfing and dying out, especially in 1924, late 1932, 1933 and 1937; frost, which killed many plants shortly after planting in spring 1936; "Red Plant", which was specially severe in the 1st planting and which occurred to appreciable extents in the 3rd and 4th plantings; "Yellow Edge", which proved disastrous in the 2nd planting; and Tarsonemid Mite, which, in the 4th planting, caused serious stunting in 1933 and 1934, with subsequent failure of the plants in the spring of 1935.

VIGOUR.

Throughout the period an attempt was made to assess the relative vigour of the plants by a system of marking. On each occasion that vigour was recorded quantitatively, each plot was assigned a value ranging from 4 to 0, the scale of marks being graduated in half points; 4 denoted very vigorous, 3 vigorous, 2 only moderate vigour, 1 poor vigour, 0 total failure. Marking was always carried out by the senior author (T.W.) and on several occasions other observers were brought in to check the observations. During the experiment the plots were marked in this way on thirty-three occasions.

The detailed data have been analysed for each planting and mean values per plot for each treatment have been extracted in each case. These are presented in Table II.

TABLE II.

Vigour Markings. Mean Values per Plot for each Planting.

Treatment.	Planting.					Totals.
	1st.	2nd.	3rd.	4th.	5th.	
A.	3·5	2·9	3·3	3·1	3·5	16·3 (1)
B.	3·1	2·7	3·6	3·0	3·8	16·2 (12)
C.	2·2	2·1	3·2	3·0	2·7	13·2 (5)
D.	2·6	2·0	3·1	2·6	2·4	12·7 (6)
E.	2·4	2·4	3·2	2·8	2·8	13·6 (4)
F.	2·0	1·9	2·7	2·4	2·7	11·7 (7)
G.	2·7	2·9	3·4	2·8	3·7	15·5 (3)
H.	1·7	2·1	2·6	2·3	2·6	11·3 (8)
Totals	20·2	19·0	25·1	22·0	24·2	

Numbers of Markings.

1st Planting = 5 ;	2nd Planting = 6 ;	3rd Planting = 9 ;
4th ,, = 8 ;	5th ,, = 5.	Total = 33.

In Table II the relative orders of the treatments for vigour, as indicated by the totals, are shown by the figures in brackets in the totals column.

The order for vigour as determined by the above method supports fully the impressions gained in the field. The three sets of plots receiving farmyard manure (A, B and G) practically always stood out above the remainder for vigour ; the shoddy plants (C) and the complete artificials (E) varied in relative vigour over the period but on the whole were similar and intermediate in vigour between the farmyard manure plots and the plots receiving the non-bulky organic manure (D). The plants under the treatments "omit potash" (F) and "no manure" (H) were definitely the least vigorous of the series.

General points concerning vigour in the various plantings were as follows :—

1st Planting (1924). Vigour was never satisfactory, perhaps due primarily to the facts that the plants at planting time in April 1924 were definitely weak from over-wintering conditions and were severely checked after planting by wet soil conditions. It is possible also that there were many diseased plants in this planting, though symptoms were masked by general weakness. Casualties on the plots were very high, as will be observed from the data in Table III showing "missing" plants from original totals of 621 per treatment.

2nd Planting (1926). Although the runners used in this planting were of excellent quality and were planted out under favourable conditions, the resultant plants were never of high vigour. This was no doubt due to the presence of Yellow Edge virus disease in the stock, since "suspected" plants were noted in October of the planting season and in the following autumn, 1927, typically diseased plants were numerous. From this time, vigour continued to deteriorate, and in May 1929 the plots could be regarded as failures, as the following vigour marking for 30/5/29 will show.

Treatments :	A.	B.	C.	D.	E.	F.	G.	H.	
	4	$3\frac{1}{2}$	$3\frac{1}{2}$	3	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$2\frac{1}{2}$	(out of a possible 12).

3rd Planting (1929). This was the most successful of all the plantings, the plants being particularly vigorous until the end of the second picking season, 1931, and only slightly less so in 1932. The farmyard manure plots always looked the most vigorous, and "omit potash" and "no manure" plots were characterized by the relatively squat habit of the plants.

4th Planting (1932). Vigour in this planting was seriously affected by very wet soil conditions during the first winter following planting, 1932-3. Specially wet areas were noted on plots D1, E1, C2, B2, D3 and E3, and considerable stunting and dying out of plants occurred. Vigour was revived to some extent during 1933, following total deblossoming of the maiden plants after severe frost injury to the blossom, but these favourable conditions were nullified in August of that year by an attack of Tarsonemid Mite. The plants showed good recovery of vigour from this attack in the spring of 1934, but a very severe attack recurred in August which led to relative failure of the plants in the spring of 1935, vigour markings being as follows on 9/5/35:—

Treatments:	A.	B.	C.	D.	E.	F.	G.	H.	
	6	5	6	5	5	4½	5	4½	(out of a possible 12).

5th Planting (1936). This planting took place in spring after a crop of mustard had been ploughed in during the previous summer, and planting operations had been postponed from the autumn owing to scarcity of runners. Planting conditions were unfavourable and hard frosts that followed planting seriously checked growth and caused many casualties. The number of refills required to replace failures on 13/7/36 was as follows:—

Treatments:	A.	B.	C.	D.	E.	F.	G.	H.
	45	48	79	79	61	70	55	59

Vigour was good during the autumn, but the winter of 1936-7 was excessively wet and the plants were again checked in the following spring from this cause. Waterlogging effects were particularly noticeable on plots C, D, E and F. in Series 3. After picking, however, conditions were favourable and growth was vigorous. During this last period, vigour on the farmyard manure plots was outstanding. Leaf scorch symptoms were marked on "omit potash" and "no manure" plots on 3/8/37.

Casualties.

The numbers of casualties were often considerable and differed greatly in the different plantings. They were not related to the manurial treatments but were caused by wet soil conditions, frost, and diseases and pests, particularly Yellow Edge, Tarsonemid Mite and Red Plant.

Although the numbers of missing plants were accurately recorded on frequent occasions throughout the experiment, these have not been considered in comparing crop yields.

Some of the data for missing plants given below will serve to show the main points.

TABLE III.

Records of Missing Plants of 621 Total per Treatment.

No. of Planting and Planting Date.	Date of Observation.	Nos. of missing Plants per Treatment.								Main Causes of Casualties.
		A.	B.	C.	D.	E.	F.	G.	H.	
1st.	24/20/24	60	82	77	58	76	84	85	140	Weak runners; waterlogging; probably also Red Plant.
April 1924.	10/7/25	73	88	81	76	87	106	94	187	
	1/6/26	77	100	95	84	139	119	104	189	
2nd.	5/8/28	107	121	138	159	140	162	117	145	"Yellow Edge" disease.
July 1926.	30/5/29	261	277	274	274	241	287	222	312	
3rd.	26/5/31	15	15	21	18	22	16	13	18	"Red Plant."
August 1929.	29/4/32	27	20	28	22	26	22	16	25	
4th.	23/5/34	78	86	55	70	98	91	110	106	Waterlogging; Tarsonemid Mite.
August 1932.	9/5/35	132	154	87	131	194	157	180	160	
5th.	13/7/36*	45	48	79	79	61	70	55	59	Waterlogging.
April 1936.	31/3/37	9	3	17	21	19	6	9	12	

* These misses replanted on this date.

DISEASES AND PESTS.

Sufficient reference has already been made to the presence and effects of certain pests and diseases on the plots and it is necessary to state here only that the data show clearly that the manurial treatments were not a vital factor in determining either the incidence of or the effects produced by Yellow Edge, Red Plant or Tarsonemid Mite.

The first and last named caused drastic failures of the plants, irrespective of widely different systems of manuring.

CROP YIELDS.

Total crop yields are available for ten seasons, between 1925 and 1937 inclusive, no crops being obtained in 1933, when the maiden plants were deblossomed; in 1935, when the blossom was destroyed by frost; or in 1936, since planting could not be carried out during the previous autumn. In all cropping seasons from 1927 inclusive, the weights of "marketable" berries were also recorded, the differences between total and marketable fruits being due to damage from various causes, mainly birds, Mildew, malformed fruits, etc.

TABLE IVa.

Showing Seasonal Crop Yields of Strawberries per Treatment (kilos).

Treatments.	1st Planting.		2nd Planting.			3rd Planting.			4th Planting.	5th Planting.	Totals.	Totals as % of "No Manure" plot.
	1925.	1926.	1927.	1928.	1929.	1930.	1931.	1932.	1934.	1937.		
A. 20 tons Dung	59·34	79·12	49·04	72·44	36·55	88·36	253·96	207·24	78·16	129·85	1054·06	136
B. 10 tons Dung + artificials	56·77	72·22	47·37	68·69	26·10	79·01	277·21	217·17	73·11	137·95	1055·60	136
C. Complete Organic (Shoddy)	44·15	48·84	34·05	58·17	27·70	46·21	244·36	205·39	77·40	103·60	889·87	115
D. Complete Organic (Dried Blood)	41·76	45·38	28·76	56·21	23·39	47·51	223·81	175·02	55·82	104·00	801·66	103
E. Complete Inorganic	46·57	40·69	39·11	62·85	38·24	66·22	238·04	182·93	62·10	99·45	876·20	113
F. Complete Organic (Dried Blood), omitting Potash	40·31	43·57	32·50	50·79	34·54	60·15	199·13	162·49	58·99	112·80	795·27	102
G. 12+8 tons Dung	48·01	73·21	49·11	70·10	43·55	80·18	224·28	202·79	65·13	161·25	1017·61	131
H. No Manure	30·55	44·60	38·27	49·58	26·65	65·48	182·01	170·57	61·42	108·10	777·23	100
Totals	367·46	447·63	318·21	488·83	256·72	533·12	1842·80	1523·60	532·13	957·00	7276·50	

TABLE IVb.

Analysis of Variance.

Variation due to	Degrees of Freedom.	Sum of Squares.	Mean Square.	$\frac{L}{S}$	5% Points.	1% Points.	Remarks.
Treatments	7	3252·97	464·71	14·6	2·14	2·89	Highly Significant.
Seasons	9	110848·27	12716·47				
Position in Field	2	255·76	127·88	4·0	3·04	4·71	Significant to 5% point.
Remainder	221	7018·23	31·76				

TABLE IVc.

Showing Significant Differences between Yields due to Manuring.

Mean Yields per Plot (kilos).

	A. 20 tons Dung.	B. 10 tons Dung + Arts.	C. Complete Organic (Shoddy).	D. Complete Organic (Dried Blood).	E. Complete Inorganic.	F. Complete Organic (Dried Blood), omitting Potash.	G. 12+8 tons Dung.	H. No Manure.
Mean Yields	35·14	35·19	29·66	26·72	29·21	26·51	33·92	25·91
Gain over "No Manure"	9·23	9·28	3·75	0·81	3·30	0·60	8·01	
Significance	Significant to 1%	Significant to 1%	Significant to 1%	Not Significant.	Significant to 5%	Not Significant.	Significant to 1%	

Standard Error of Mean =1·025
Significant Difference for 1% point =3·75
" " " 5% " =2·85

TABLE IVd.

Showing Total Yields of Marketable Fruit per Treatment (kilos) and percentage Marketable of Total Crops (Period 1927-1937).

	A.	B.	C.	D.	E.	F.	G.	H.
Total Marketable Yields	741·74	756·66	648·75	586·69	637·96	584·45	737·60	581·52
% of Total Yields	81·0	81·5	81·3	82·0	80·8	82·0	82·2	82·7

Since a number of pickings were necessary for each crop, the detailed records also show whether the treatments affected earliness or lateness of the crops, but examination from this point of view does not show any significant effects due to the manures.

The effects of the treatments on the quality of the fruits from the 1931 crop were fully reported in the previous paper (4).

The data for yields have been analysed statistically, the method used allowing of the estimation of seasonal effects.

The summarized data, together with the relevant statistical analysis, are given in Tables IVa-IVd.

The analysis shows that all the manurial treatments, excepting "Complete Organic" (dried blood), D, and that treatment but omitting potash, F, have given significant increases in yields, treatments A, B, C and G, to the highly significant 1 per cent. point and treatment E to the 5 per cent. point. The yields under all the farmyard manure treatments are similar and are significantly higher than those on the shoddy plots. The latter plots and the "Complete Artificials" are not significantly different. The results for treatments D and F suggest that dried blood is not an effective source of nitrogen for strawberries, and because of this, the effect of potash omission on yield cannot be assessed.

Table IVd shows that the percentages of marketable to total crops were not influenced by manuring.

TABLE V.

Comparison of Crop Yields at Long Ashton and Botley.

Long Ashton, 10 crops; Botley, 8 crops.

(*No treatment G at Botley, hence this omitted.*)

Treatment	A.	B.	C.	D.	E.	F.	H.
Long Ashton : Mean Yields (kilos)	35·14	35·19	29·66	26·72	29·21	26·51	25·91
Increase over "No Manure" significant to:	1%	1%	1%	Not Significant	5%	Not Significant	
Order of Yields	2	1	3	5	4	6	7
Botley : Mean Yields (kilos)	18·58	17·12	17·75	16·85	18·99	15·74	12·82
Increase over "No Manure" significant to:	1%	1%	1%	5%	1%	Not Significant	
Order of Yields	2	4	3	5	1	6	7

It is of interest to compare the results for yields in this experiment with those, also for Royal Sovereign, in the parallel trials at the Botley Station, where yields were much more affected by pests and diseases than at Long Ashton. The comparison is shown in Table V, where it will be seen that the agreement in the two cases is very close.

Data for Mustard.

After ploughing up the 4th planting in May 1935, the plots were subsoiled and sown with mustard as a cover crop on June 5th. When the plants were just coming into flower, on July 11th, four areas, each one square metre, were cut and weighed on each plot. The yields for the cut areas obtained in this way are given for each treatment in Table VI.

Table VI.

Comparative Crop Yields for Mustard (kilos per 12 sq. metres).

	A.	B.	C.	D.	E.	F.	G.	H.
Yields in kilos	21·08	22·64	18·57	22·97	23·12	21·82	22·71	14·07
As % "No Manure"	150	161	132	163	164	155	161	100
Order of Treatments	6	3	7	2	1	5	3	8

In considering the results in Table VI, it should be remembered that the last dressings of dung and the last dressing of shoddy had been applied to plots A, B and C in August 1932, prior to the 4th planting. In treatment G, 12 tons of dung had been applied in August 1932 and 8 tons in March 1934.

Plots receiving artificial fertilizers, i.e. treatments B, C (phosphates and potash only), D, E and F, had all received the annual dressings on March 1st, 1935, i.e. three months prior to sowing the mustard.

The results have not been analysed statistically, but from a superficial examination the data suggest that the order of yields was determined by the presence of available nitrogen in the soil.

Thus, all plots receiving a nitrogenous dressing in a complete manure in spring 1935, viz. E, D and B, are in a group showing high yields. Treatment G is also in this group, and since this plot received the same amount of dung as in treatment A, but in two applications instead of one, it would seem that the former method ensures a steadier level of available nitrogen over the three-year period given to each planting of strawberries.

The high yield for treatment D, where dried blood was used, is of interest, since, for strawberries, both at Long Ashton and Botley, this treatment has given poor results.

Shoddy shows much the lowest yield, and next, dung at 20 tons previous to planting, and it would appear that under these treatments nitrogen availability at the end of the three-year period is relatively low. Comparison of treatments D and F suggests that even with mustard, potash omission is possibly of importance on this soil.

CONCLUSIONS.

GROWTH CHARACTERS AND VIGOUR.

1. Differences in growth characters resulting from manurial treatments were shown most clearly in July, after the fruiting season. Purpling of the foliage was the most general symptom of exhaustion, but marginal leaf scorch was also shown where potash was not given. Dung treatments produced relatively luxuriant foliage, and where potash was omitted the plants were rather squat in habit.

2. Manurial treatments affected vigour in the following way: farmyard manure produced vigorous growth; complete artificials and complete organic manure, with shoddy as a source of nitrogen, resulted in medium vigour; complete organic, with dried blood as a source of nitrogen, gave plants of only moderate vigour; vigour was not increased over that of the no manure plants where potash was omitted from the dried blood manure.

3. Vigour was greatly affected by the following factors: soil wetness, especially from wet winter conditions; frost immediately after planting; weak runners; Red Plant and Yellow Edge diseases, and Tarsonemid Mite.

CASUALTIES.

4. Casualties were mainly due to the factors mentioned under 3 and were not related to the manurial treatments.

DISEASES AND PESTS.

5. These factors produced profound effects. Red Plant disease was severe in the 1st planting and also prevalent in the 3rd and 4th plantings. Yellow Edge disease was severe throughout the 2nd planting and caused failure of the plants in the third season. In the 4th planting, Tarsonemid Mite greatly checked vigour in August of the second season and caused complete failure in the following season.

6. The incidence of and effects produced by the above diseases and pest were not related to the manurial treatments.

Crop Yields.

7. All dung treatments and the complete organic fertilizer containing shoddy produced highly significant increases (1 per cent. point), the yields for the former being also significantly higher than for the latter.

8. Complete artificials resulted in increased yields significant to the 5 per cent. point, but the complete organic manure containing dried blood as a source of nitrogen did not produce any significant increase. Dried blood appeared to be a poor source of nitrogen for strawberries.

9. The effect on crop yield of potash omission from the complete "dried blood" manure could not be determined owing to the lack of response to the complete "dried blood" manure.

10. The orders for vigour and yield showed good agreement.

11. The order of yields from the various treatments agreed well with those obtained in the parallel experiment with Royal Sovereign at the Botley Station.

12. The manurial treatments did not affect time of ripening or the proportion of marketable berries in the total crops.

Growth of Mustard.

13. The growth of mustard, at the end of a three-year planting period, appeared to reflect the availability of nitrogen from the manurial treatments and did not reflect the performance of the strawberry plants in the experiment.

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SUMMARY.

1. A field manurial experiment on strawberries, consisting of five plantings and carried out at Long Ashton from 1924 to 1937, is described.

2. The treatments included three dung treatments, complete organic manures containing shoddy and dried blood respectively as sources of nitrogen, the dried blood organic without potash, a complete artificial fertilizer and no manure.

3. Records were obtained over the period relating to general growth characters, vigour, incidence and effects of diseases and pests, casualties to plants and total and marketable yields of fruits.

4. Growth characters and vigour were affected by the various manurial treatments. Dung produced relatively luxuriant foliage and the greatest vigour; results from shoddy and complete artificials treatments were similar; dried blood manure with and without potash gave relatively poor vigour. Purpling was the most general symptom of exhaustion shown by plants, but marginal leaf scorch was also present where potash was not given.

5. Red Plant and Yellow Edge diseases and Tarsonemid Mite produced profound effects on vigour and dying off of plants, and the two latter each caused the complete failure of a planting.

The incidence of and effects produced by the diseases and pest were not related to the manurial treatments.

6. Casualties were very heavy in certain plantings and were attributed to poor quality of runners, frost following planting, wet soil conditions especially in winter, Red Plant and Yellow Edge diseases and Tarsonemid Mite.

7. Yields were significantly increased by all manurial treatments excepting the two in which dried blood was used. This ingredient appeared to be a poor source of nitrogen for strawberries. The largest yields were obtained on the dunged plots.

Manuring did not affect the ripening season or the proportions of marketable fruits in the total crops.

8. Yields of mustard, grown at the end of a three-year planting period, appeared to reflect the availability of nitrogen from the various manurial treatments and suggested low availability of this element at that time from dung and shoddy dressings applied three seasons previously.

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SOME OBSERVATIONS ON THE EFFECTS OF BORON TREATMENT IN THE CONTROL OF "HARD FRUIT" IN CITRUS*

By A. A. MORRIS

Chemist, British South Africa Company's Mazoe Citrus Experimental Station, S. Rhodesia

INTRODUCTION.

In a recent publication (1) the writer recorded the progress of experimental work which finally established a deficiency of boron as the underlying cause of a serious and widespread physiological disorder in citrus trees known as the "hard fruit" disease which occurs extensively in certain areas in Southern Rhodesia given over to the cultivation of this crop on a commercial basis.

Details of the economic significance of the malady were given together with a description of its more obvious features in the field. Furthermore, it was shown that some of the characteristics described by Haas and Klotz (2) as typical of boron deficiency in citrus were not specific for this country, where several symptoms hitherto unrecorded have now been established as associated with boron starvation in citrus under local field conditions.

Since the publication of the above paper, confirmatory data on the extreme effectiveness of boron treatment in the eradication of the "hard fruit" problem in the field have been obtained, and these, together with analytical evidence of certain modifications brought about in the composition of fruit and leaves from experimental trees, form the basis of the following paper.

For a better understanding of the nature of the "hard fruit" disturbance, six photographs illustrating the more salient characteristics of the disorder are included. Four of these have already appeared in the publication (1) above referred to.

Grateful acknowledgment is made of the assistance given by members of the field staff of the Mazoe Citrus Estate in carrying out much of the field experimental work hereinafter recorded.

EXPERIMENTAL TREATMENTS.

Grove 31T (Area I).

In December 1935, five sixteen-year-old Valencia Late trees, growing on shallow soil underlain by gravel, were treated with top dressings of powdered borax ($Na_2B_4O_7.10H_2O$) at the rate of 100, 200, 300, 400 and 500 grammes per tree respectively. The applications were distributed evenly throughout

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the irrigation basins and subsequently worked in lightly by hand, the necessity for irrigation being obviated by the imminence of rain.

Grove 30L (Area II).

In January 1936, five sixteen-year-old Valencia Late trees growing on open-textured red loam in a very badly eroded area were treated in the above manner at the respective rates of 600, 700, 800, 900 and 1,000 grammes of powdered borax per tree.

Grove 14T (Area III).

In May 1936, six eighteen-year-old Valencia Late trees growing on extremely shallow soil underlain by heavy boulder accumulation and suffering acutely from the effects of marked soil erosion were treated with aqueous solutions of borax at the rate of 25, 50, 100, 150, 200 and 250 grammes per tree respectively. These soil dressings were immediately followed by irrigation. The above treatment, using the same quantities of borax per tree, was repeated in July 1936.

The three experimental areas were widely separate and the trees chosen were in an advanced stage of "hard fruit" decline. Crops were negligible in amount and valueless in quality (Figs. 1 and 2). Vegetative growth was greatly retarded, with much "dieback" in evidence (Fig. 6).

Treatments were applied too late to be of value in saving or improving the "in season" crop for 1936. In a very short time, however, treatment effects became clearly visible in a rapid improvement of vegetative condition with development of profuse long stemmed growth entirely devoid of leaves showing characteristic "spotting" (Figs. 3 and 4).

Out of season fruit which subsequently set in Areas I and II showed no trace of the abnormalities associated with "hard fruit". It is of interest to note that the vegetative response by citrus trees to boron treatment is in marked contrast to that of apple trees suffering from "internal cork" as recorded by Askew (3).

Finally, it may be recorded that in spite of relatively excessive applications of borax to the experimental trees in Area II, no characteristic leaf injury typical of boron excess (4) has been noted to date (February 1938). On the other hand, no recrudescence of "hard fruit" symptoms has been found on any of the treated trees since the date of original treatment.

FRUIT INVESTIGATIONS.

Investigations on fruit were restricted to the estimation of the following:—

I. Boron.
II. Nitrogen and inorganic nutrients.
III. Total sugars and pectins.

A record of the methods of analysis employed in the above analyses is included in an appendix which accompanies this paper.

I.

Since no data are available on the boron content of boron deficient oranges, it was considered to be of interest to ascertain whether fruit from trees under boron treatment would show an improved boron content by comparison with the content found in apparently normal and in diseased fruits of the same age at any given period of the growth cycle.

For this purpose, material was collected both from experimental trees and from controls in their near vicinity at regular monthly intervals during the period December 1936 to March 1937.

The system of sampling consisted in collecting an equal number of fruits from each experimental tree in each area. To ensure that all fruits were as nearly as possible in the same stage of growth, every fruit was accurately graded on the tree, before picking, by means of a ring cut to a size considered representative of the average size of individual fruits in each month in which sampling took place.

The nature of the "hard fruit" disease eliminated the possibility of using an equal number of standard control trees during the period of investigation. Owing to the excessive loss of crop which occurs in badly affected trees during the period December to March, it was found necessary to select samples of apparently healthy and diseased fruit from random trees in the very near vicinity of the experimental trees in each area. As such, control fruit samples were not necessarily picked from the same trees in any given month. All fruit, however, was graded in the manner above described, the total number of fruits comprising the bulk sample being identical with that picked from the experimental trees in any given month. The number of fruits picked in each sample consisted of 25 in December and January, 20 in February, 15 in March and 10 in July. Apparently normal and "hard fruit" were collected from the same area and frequently from the same trees, the presence or absence of internal discoloration and gumming constituting the criterion of unhealthiness or normality in the samples collected. It will be apparent, therefore, that the distinction between these two classes of fruit in this paper is a narrow one, and that on the system of sampling adopted (i.e. standard sizing) by no means the worst examples of "hard fruit" were picked in any given month.

No sampling was carried out for "hard fruit" after March, since after this date it was almost impossible to find samples which were comparable with those from boron treated trees, using the size standard as a measure of development.

The samples of mature fruit picked in July were representative of boron treated and healthy fruit only.

All material collected was subsequently dried at a temperature not exceeding 80° C. After grinding to a fine powdery condition the samples were preserved in air tight bottles. Aliquots from these samples supplied the material for all the fruit analyses recorded in this paper.

(It should be pointed out that only five of the six treated trees in Area III were used for the collection of samples. The tree under treatment with 500 grammes of borax in this area was excluded, to allow of an equal number of fruits to be picked from each experimental block. As such, fruit samples from each area are representative of a mean borax treatment of 300, 800 and 210 grammes per tree in experimental Areas I, II and III respectively.)

The results obtained in the analysis of the above samples for boron content are included in Table I.

Inspection of the above values shows that the amount of boron found in fruit from treated trees considerably exceeds that present in either class of control fruit on any corresponding date during the period investigated.

The differences in values found in the two types of control fruit, on the other hand, are relatively small.

In general it will be seen that the amount of boron in fruit from trees under treatment remains relatively constant during that period of the growth cycle investigated. Between December and July there is a fall of only some 2 parts per million in material from Areas I and II, in Area III a steeper drop of some 8 parts per million is recorded.

Somewhat similar results are found in the analysis of apparently healthy fruit from untreated areas.

With the exception of the results from Area II during January and February, it is seen that during the months December to March, boron values in diseased fruit show relatively little change.

An examination of mean values from each locality shows that the amount of boron in fruit samples from the three experimental areas varies from a maximum of 23·6 parts per million in Area II under the highest average treatment per tree (800 grammes) to a minimum of 17·2 parts per million in Area III under the lowest average treatment per tree (210 grammes).

Mean values for boron for each untreated area vary between 8·3 and 10·3 parts per million for apparently healthy fruit and 5·3 and 6·9 parts per million for diseased fruit.

The foregoing data, therefore, show that an early and measurable increase in the boron content of Valencia Late citrus fruit follows the application of borax top dressings on local soils deficient in boron, and that the intake of this

TABLE I.

Parts per million of Boron in Dry Matter of Young and Mature Oranges.

Date.	Area I.			Area II.			Area III.		
	Treated.	Untreated (Healthy).	Untreated (Diseased).	Treated.	Untreated (Healthy).	Untreated (Diseased).	Treated.	Untreated (Healthy).	Untreated (Diseased).
Dec. 1936	20·6	12·3	4·9	24·2	12·1	8·4	19·3	7·2	6·0
Jan. 1937	21·3	8·5	5·1	23·1	10·0	4·9	18·5	11·9	6·3
Feb. 1937	20·1	8·9	6·3	22·4	8·9	5·1	17·4	7·4	7·4
March 1937	18·7	7·4	4·9	25·8	13·0	9·0	19·4	8·9	7·7
July 1937	18·1	9·2	—	22·4	7·3	—	11·4	6·3	—

element is continued throughout the growing period in amounts which are in relatively constant proportion to the dry weight of the fruit at any of the stages of growth investigated.

There is also some evidence that a small increase in the boron content is sufficient to prevent the appearance of "hard fruit" symptoms in apparently healthy fruit growing on trees showing unmistakable signs of boron deficiency in the field.

II.

In view of the importance which attaches to the presence of minute quantities of boron in the regulation of the normal metabolism of the citrus tree, it was thought advisable to ascertain whether any marked variation in the intake of the more common nutrient elements would be found in a comparative analysis of boron treated apparently normal fruit and "hard fruit" during the earlier stages of growth.

Analyses for total N, P (inorganic), K and Ca were consequently carried out on material from the aforementioned samples with results which are shown in Table II. It should be noted that fertilizer treatment of control and experimental trees was identical in Areas II and III. In Area I, however, additional heavy dressings of nitrogen (as sulphate of ammonia) were given to the five experimental trees following the application of boron treatments in December 1935. For this reason the results of analyses of fruit samples from Areas II and III only are recorded in Table II.

A consideration of the above data shows that values for nitrogen decrease steadily with increase in age in all fruit samples. It will be noticed, however, that in each area nitrogen values in treated fruit are lower than those found in both types of control fruit picked on corresponding dates. Furthermore, with one exception, severely affected fruit samples show somewhat higher values for this element on any given date than corresponding samples of apparently healthy fruit picked at the same time.

Inorganic phosphorus values on the other hand, although they also show a tendency in general to decline during the investigational period, show variations which are neither marked nor consistent enough to suggest an association with particular treatment.

Values for potassium and calcium also appear to be without significance in relation to treatment, the tendency towards higher concentrations of the latter element in treated fruit (notably in Area III) being readily explained by the already established antagonistic intake relationship existing between nitrogen and calcium (5).

The evidence of the above data therefore suggests that with the possible exception of a reciprocal relationship between the intake of boron and nitrogen,

TABLE II.

Total N and Inorganic Constituents as percentages of Dry Matter of Immature Oranges.

Date		Area II.			Area III.		
		Treated.	Untreated (Healthy).	Untreated (Diseased).	Treated.	Untreated (Healthy).	Untreated (Diseased).
Dec. 1936 ..	N.	1·31	1·34	1·41	1·28	1·34	1·34
	P.	0·13	0·12	0·15	0·15	0·13	0·15
	K.	0·87	0·81	0·86	1·11	1·20	1·11
	Ca.	0·80	0·92	0·83	0·96	0·80	0·82
Jan. 1937 ..	N.	1·27	1·33	1·29	1·11	1·21	1·24
	P.	0·09	0·11	0·12	0·11	0·12	0·11
	K.	1·15	1·17	1·08	1·03	1·09	1·09
	Ca.	0·99	0·95	0·97	1·01	0·90	0·89
Feb. 1937 ..	N.	1·09	1·16	1·19	0·96	1·02	1·17
	P.	0·09	0·10	0·13	0·10	0·09	0·10
	K.	1·14	1·05	1·07	0·95	0·90	0·96
	Ca.	0·93	0·88	0·90	0·98	0·91	0·84
March 1937 ..	N.	0·91	0·98	1·07	0·95	0·96	1·09
	P.	0·09	0·11	0·10	0·11	0·10	0·11
	K.	0·96	1·04	0·86	0·86	0·73	0·95
	Ca.	0·91	0·80	0·81	0·98	0·87	0·75

there is relatively little interference in the intake of the commoner nutrient elements under conditions of boron deficiency in the field.

III.

Many investigators, notably Haas and Klotz (2) in their work on citrus leaves and shoots, have recorded a disintegration of the cambium and phloem tissue as characteristic of severe boron deficiency in the plant material investigated. As a result of the disorganization of the phloem elements, translocation of elaborated products such as sugars is in greater or less degree impeded.

Since no work has previously been carried out on the effect of a boron deficiency on citrus fruits, estimation of total sugars and pectins was carried out on both treated and control fruits to determine whether evidence of impeded translocation of these products would be found in young oranges growing under field conditions of boron deficiency. The results obtained on the above

investigation are included in Table III. Total sugars were estimated as invert sugar and total pectins as calcium pectate.

Total Sugars.

Values for sugars show a consistent tendency to rise in all fruit samples during the period under review. While the increase is relatively small during the first three months, a sharp rise occurs in all values between February and March.

In Areas I and III, the amount of sugar found in treated fruit is consistently higher than that found either in apparently healthy or in diseased fruit picked on corresponding dates. Similarly the sugar content in fruit in apparently healthy condition invariably exceeds that found in obviously diseased fruit of the same age in these two areas.

In Area II, however, it is seen that sugars in apparently healthy fruit tend to exceed in amount that found in both treated and diseased fruit of corresponding age, and that the sugar content in treated fruit in February barely exceeds that found in the "hard fruit" samples picked in that month. In March, the sugar content of treated fruit actually falls below that of "hard fruit".

It would appear, therefore, that under conditions of boron deficiency, the translocation of sugars to the citrus fruit is retarded in greater or less degree, depending on the severity of the incidence of the "hard fruit" disease. Moreover, it seems probable that an optimal limit in the use of boron exists in the improvement of the translocation procedure. When relatively excessive amounts of this element are used, as in Area II, there is some evidence that the translocation of sugars falls below that found in normal fruit and even of diseased fruit, without, however, the development of any apparent abnormalities in the structure of the fruit itself.

Total Pectins.

The data included in Table IV are of interest as showing that total pectic substances (as calcium pectate) are universally higher in treated fruit than in either class of control fruit in any given month in all areas. This finding is of interest in view of the relatively higher proportion of peel to pulp found in "hard fruit" in all stages of the malady than in fruit from boron treated trees. Unlike sugars, the pectin content in treated fruit, and to a less extent in apparently healthy and diseased fruit, remains relatively constant during the period investigated.

The universally higher sugar values found in apparently healthy fruit when compared with those from diseased fruit is not reflected in a corresponding increase in pectin values. It is seen, on the contrary, that if values for December are excluded, the pectin content of diseased fruit tends to exceed that found in

TABLE III.

Total Sugars as percentages of Dry Matter of Immature Oranges.

Date.	Area I.			Area II.			Area III.		
	Treated.	Untreated (Healthy).	Untreated (Diseased).	Treated.	Untreated (Healthy).	Untreated (Diseased).	Treated.	Untreated (Healthy).	Untreated (Diseased).
Dec. 1936	9·75	8·60	7·32	8·27	8·25	7·34	8·89	7·90	6·21
Jan. 1937	9·98	9·69	7·75	9·96	10·06	7·80	10·01	8·46	8·03
Feb. 1937	13·55	12·22	9·64	10·33	13·75	10·04	12·77	11·70	11·29
March 1937	18·96	17·03	16·55	18·50	20·40	19·36	19·90	18·82	18·03

TABLE IV.

Total Pectins as percentages of Dry Matter of Immature Oranges.

Date.	Area I.			Area II.			Area III.		
	Treated.	Untreated (Healthy).	Untreated (Diseased).	Treated.	Untreated (Healthy).	Untreated (Diseased).	Treated.	Untreated (Healthy).	Untreated (Diseased).
Dec. 1936	25·77	23·34	21·47	26·26	22·66	19·70	24·68	21·66	19·24
Jan. 1937	26·12	21·69	22·20	27·94	23·24	22·90	27·83	20·59	22·89
Feb. 1937	26·29	19·87	21·87	27·89	20·51	22·89	27·44	20·21	23·74
March 1937	25·76	23·76	24·78	25·95	22·22	22·96	25·59	19·18	22·70

apparently healthy fruit during the succeeding three months. This is most marked in values for the two types of control fruit from Area III.

An explanation of this apparent anomaly is not offered at this juncture, but the possibility is not overlooked that the varying quantity of gum universally found in badly diseased fruits might, on the system of extraction and hydrolysis adopted, give rise to acids closely associated with pectic acid and, like it, capable of forming insoluble calcium salts.

For purposes of this paper it is sufficient to show that there is considerable evidence that pectic substances are retarded in their translocation to the citrus fruit under conditions of boron deficiency in the field. It is also seen that relatively excessive applications of boron do not inhibit the translocation of pectins in the same manner as they appear to inhibit that of sugars.

LEAF INVESTIGATIONS.

Owing to the extensive work carried out by American investigators on the boron content of citrus leaves, investigations on leaf material by the writer have been confined to

I. Estimation of boron content in leaf material at the beginning and end of a growing season ;

II. Survey of boron status in random samples of leaves to determine a possible relationship between such status and the degree of severity of the "hard fruit" problem in any particular area.

I.

In September 1936, young leaves from both boron treated and control trees were picked some three weeks after the first appearance of spring growth. At this early stage, spotting in boron deficient leaves (Figs. 3 and 4) was easily discernible, enabling accurate sampling of affected leaves to be carried out without difficulty.

In April 1937, samples from the same areas were again picked, care being taken to choose only mature well grown leaves. The results of subsequent analysis of this material are recorded in the following Table :—

Table V.

Parts per million of Boron in Dry Matter of Leaves.

Age of Leaves.	Area I.		Area II.		Area III.	
	Treated.	Untreated.	Treated.	Untreated.	Treated.	Untreated.
Very young	34·2	5·8	76·7	4·6	28·3	4·6
Mature	95·5	11·3	240·0	8·7	41·0	6·1

It is evident that the effects of boron treatment are early manifest in young leaf growth at the beginning of the growing period. Although the number of leaves taken from each experimental tree was only approximately similar, it is seen that the amount of boron found in each sample is roughly proportional to the amount of borax applied. By contrast, the boron content of diseased leaves is consistently maintained at a low level.

In mature leaf samples, a marked increase in the boron content is apparent in material from treated trees and a relatively small one in that from the control areas. Values in the former are again roughly proportional to the amount of borax applied.

This increase in boron content in leaf material with increasing age is in agreement with observations made by Kelly and Brown (5).

II.

Random sampling of leaves from twenty-one groves of the S. Section of the Estate were picked in May 1937 prior to general boron applications throughout the Estate in June of that year. The leaves were of all ages and were picked from areas most typical of the condition of the grove as a whole. The bulk sample collected consisted of material from every tree in a selected row. With one exception (Grove 20T) all the groves are of the Valencia Late variety. The results of subsequent analysis of these samples are shown in Table VI.

TABLE VI.

Parts per million of Boron in Dry Matter of Leaves.

Grove.	B p.p.m.	Incidence of Hard Fruit.
8	14·5	Nil.
9	17·0	
10L.	18·4	
10T.	12·8	Slight.
11T.	11·3	
11L.	8·4	
16L.	11·3	
*17T.	26·9	
17L.	11·3	
18T.	12·7	
12T.	7·1	Severe.
12L.	4·3	
13T.	5·7	
13L.	7·1	
14T.	5·7	
14L.	4·3	
15T.	5·7	
15L.	11·3	
16T.	7·1	
17L.	8·4	
20T.	8·4	

* This grove was treated with 50 gm. borax per tree in the preceding November.

Considering the varied nature of the material picked, these figures in general are in good agreement with the degree of "hard fruit" infection obtaining in each area.

It is of interest to note that whereas it has been shown that boron in excess tends to accumulate in the leaves of citrus trees under conditions of deficiency in the field (5), relatively small differences are found in the content of this element in affected leaves and fruit, as reference to Table I will indicate.

FIELD INVESTIGATIONS.

The value of boron in improving the vigour of Valencia Late trees suffering from a deficiency in this element is best shown by the final results obtained both in the quantity and quality of fruit produced by the experimental trees at harvesting in July 1937.

I.

For the purpose of estimating the effect of boron treatment on cropping, detailed data on the results obtained from Area III in July 1937 only will be discussed. In doing so it will be understood that equally striking results were obtained from Areas I and II, although time did not permit of the counting and grading of the fruits from each tree to be carried out in these areas.

For purposes of comparison the total crop from six control trees in Area III was also picked, counted and subsequently graded on the same day. These trees are situated in the same row as the experimental trees, four being immediately above and two immediately below the experimental area. The results of comparison are shown in the following Table:—

TABLE VII.

Record of Crops from Treated and Control Trees in Area III, July 1937.

	Treated Trees.						Control Trees.					
Borax in gm. per tree	500	*400	300	200	100	50	—	—	—	—	—	—
Total yield in fruits per tree	1,286	1,017	1,714	2,272	2,181	1,941	830	129	310	822	836	1,700
No. of "hard fruits" found	—	—	—	—	—	—	653	124	270	752	694	1,346

* Undersized tree.

It is seen that in spite of identical growing conditions and fertilizer treatment, the yield from the experimental trees (10,411 fruits) greatly exceeds that from the control trees (4,627 fruits).

Crops from both areas were subsequently graded in the packhouse, culling being restricted solely to "hard fruit". It is evident that as no "hard fruit" was found in the crop from the treated trees, on this score the 10,411 fruits produced were potentially marketable. On the other hand it is seen that no less than 3,839 fruits out of a total of 4,627 from the control trees were unmarketable, leaving a potential commercial crop of 788 fruits.

These figures collectively illustrate the profound effect of advanced boron deficiency in reducing crops in citrus trees, not only by loss of fruit during the growing period, but in the subsequent grading for quality which is carried out in the packhouses.

II.

Earlier observations by the writer (1) that boron played an important part in the efficient use of available soil moisture reserves by the citrus tree were to some extent substantiated by the marked increase in turgor noticed in developing fruits picked from the experimental trees at all stages of growth during the 1936-7 season.

To ascertain whether a corresponding improvement in juice percentage was likely to be found in mature fruit at export picking stage, samples of ten fruits each (226 count) were picked from each experimental area and from control trees in July 1937 and subjected to tests as laid down in the Export Regulations of the Department of Agriculture of the Union of South Africa, with results which are shown hereunder.

TABLE VIII.

Maturity Test Data from Experimental and Control Areas, July 1937.

Treated.					Untreated.				
Area.	% Juice.	% Acid.	% S.Solids.	Ratio.	Area.	% Juice.	% Acid.	% S.Solids.	Ratio.
I.	53·55	1·81	12·18	6·73	I.	45·65	1·53	11·48	7·50
II.	53·38	1·82	11·58	6·36	II.	48·88	1·63	11·08	6·80
III.	51·22	1·71	11·12	6·50	III.	46·79	1·60	10·92	6·82
Mean	52·72	1·78	11·63	6·53	Mean	47·11	1·59	11·16	7·04

The above results show that a very marked improvement is found in the juice percentage of the fruit from treated trees when compared with that found in normal untreated fruit from control trees.

Fruits under treatment also show a higher soluble solids content. This favourable result is somewhat offset by a universally higher acid content, which suggests that treatments had a somewhat retarding effect on maturity in the season under review.

SUMMARY.

The foregoing paper deals with certain effects of boron treatment in the control of "hard fruit" in citrus.

Experimental treatments and methods of sampling fruits are discussed.

Subsequent analyses show that the boron content in fruits is increased by boron treatment and that "hard fruit" symptoms are associated with a low content of this element.

It is also shown that with the possible exception of nitrogen, the intake of the more common nutrient elements by the young citrus fruit does not appear to be influenced by boron treatment. On the other hand it is found that sugars and pectins are lower in boron deficient fruit than in fruit from trees under relatively low boron treatment. Under high boron treatment, however, there is some evidence that the sugars, but not the pectins, are retarded rather than stimulated in their translocation to the fruit.

The analysis of leaves shows that boron treatment is early reflected in an enhanced boron content in the leaf at an early stage of growth and that boron accumulates in the leaf with increasing age. As with fruit, leaves from "hard fruit" trees are found to be very low in boron.

Analyses of twenty-one samples of leaves picked at random show that varying boron status is correlated with varying severity of "hard fruit" incidence.

Crop results from treated and control trees are given and show that severe losses of fruit are occasioned by a deficiency of boron, not only during the growing season but also subsequently in the packhouse.

Maturity test data for 1937 indicate that the percentage of juice and soluble solids is increased in mature fruit by boron treatment, but that the maturing process is somewhat delayed.

APPENDIX.

Analytical Methods Employed.

Boron: 20-25 gm. oven dried material (70°-80° C.) were treated with excess caustic soda, oven dried and ashed in an electric muffle at a low temperature. The charred residue was extracted with water and filtered into copper beakers. The alkaline filtrate was evaporated to dryness, ignited and transferred with water to a 100/110 c.c. sugar flask. The residue from first ashing was re-ignited after addition of a little lime water to a white ash which was then dissolved in dilute HCl and the solution added to the alkaline solution in the sugar flask. This solution was then made acid with HCl, and calcium chloride added. The solution was then made alkaline to phenol phthalein and made up to 110 c.c. with water and 10 c.c. of lime water. After shaking,

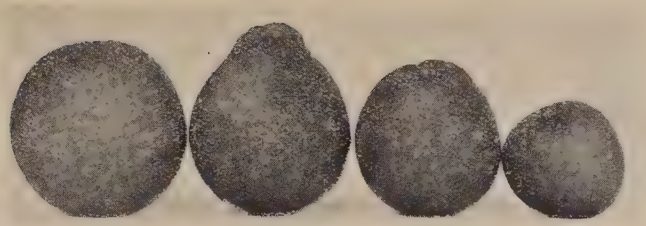

FIG. 1. One fruit from boron treated tree on extreme left, and three fruits from boron deficient trees. All fruits from same setting approximately 9 months old. $\times \frac{1}{2}$.

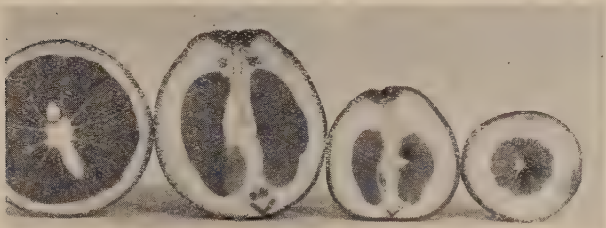

FIG. 2. Above fruits cut to show internal condition. Boron deficient fruits showing rind thickening, low juice content, absence of seeds, gumming and discoloration. $\times \frac{1}{2}$.

FIG. 3. Spotted leaves from boron deficient trees. Reflected light.

FIG. 4. Same leaves by transmitted light.

Fig. 5. Nineteen-year-old Valencia Late tree from Area III eleven months after treatment with 50 gm. of borax.
1936 crop: 107 fruits. 1937 crop: 1,941 fruits. Photo taken June 1937, one month before harvesting.

Fig. 6. Nineteen-year-old Valencia Late tree from Area III untreated, showing advanced boron deficiency symptoms.
1937 crop: Nil. Photo taken June 1937.

the solution was filtered and boron estimated in the filtrate according to the method given by Wilcox (7) except that n/25 lime water was used in place of .046n.NaOH.

Nitrogen: Kjeldahl, with $CuSO_4$ and K_2SO_4.

Phosphorus: Colorimetric, with ammonium molybdate and stannous chloride.

Potassium: Volumetric, as potassium cobalti-nitrite.

Calcium: Volumetric, as calcium oxalate.

Sugars: Soxhlet extraction for eighteen hours with 80 per cent. alcohol. Alcohol evaporated and residue taken up with hot water. The solution was then cleared with lead acetate and potassium oxalate and inverted with conc. HCl. After neutralizing, an aliquot of the solution was used for determination of total sugars according to the method of Lehmann-Schoorl (8).

Pectins: Material extracted with hot 0·5 per cent. ammonium oxalate for twenty-four hours after the method of Nanji and Norman (9) and the pectins in solution subsequently estimated as calcium pectate according to the method of Emmett and Carre (10).

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BOOK REVIEWS

SCIENTIFIC HORTICULTURE, Vol. VI, 1938. The Horticultural Education Association. (Obtainable from R. T. Pearl, at the S.E. Agri. Coll., Wye, Kent. 4s. net.)

The latest volume of this annual publication well maintains the standard set by the earlier issues. It is the largest of the series, but this is mainly due to the inclusion of the papers read at the Third Revision Course in Horticulture, held at the University of Reading in September 1937. This section constitutes Bulletin 50 of the Faculty of Agriculture and Horticulture of the University, and occupies 142 of the 252 pages of the text. It comprises a valuable series of original papers on many aspects of commercial flower production, designed to give the latest practical and scientific knowledge acquired by experience and research in this important industry.

This part begins with a statistical survey of the industry to-day by Dr. H. V. Taylor, which traces the development of commercial flower-growing, its regional distribution and the financial aspects. It is followed by practical articles of great value, contributed by leading growers, on the cultivation of chrysanthemums, carnations and pot plants. Then follows a series of papers from research workers on pests and diseases of these crops and also of roses and ornamental plants.

It is not possible to deal with all the papers individually, but special mention might be made of that by Fox-Wilson on pests of commercial ornamental plants, which includes a valuable reference list of the chief pests of these crops. Two papers on plant breeding follow, one by Lawrence on plant improvement and the other by Miss Scott-Moncrieff on the nature and inheritance of flower colour, which gives a most excellent review of the latest research in this subject. Tincker reviews the theory and practical applications of photoperiodism in horticulture, and the Bulletin concludes with two informative papers on flower-marketing, one by Mr. George Monro from the saleman's viewpoint and the other by Capt. Moyses Stevens on the problem as seen by the florist.

The papers contributed directly to the Journal are in many respects complementary to the above and to those of the 1935 and 1937 volumes. Miss Purvis contributes the second part of her paper on the Dutch research work on growth and flowering of bulbs, dealing this time with tulips and daffodils, hyacinths having been considered in the previous volume.

Similarly, Thomas completes his review of growth-promoting substances, confining his attention in this part to the vexed question of the influence of external organic substances, including "bios", auximones and the animal follicular hormones, on the growth and flowering of plants. Greenhill reviews recent work on boron deficiency in horticultural crops, a particularly interesting part in this being the attribution of "cork" and "drought spot" of apples to deficiency of this element.

Papers on chromosome mechanism and potato virus research follow, the latter giving a most valuable account of the analysis of virus infections and the production of virus-free seed tubers.

To the fruit grower the papers by Crane and Swarbrick will be of special interest, the first being a summary of the practical points in cherry cultivation arising from the work described in a previous number of the JOURNAL OF POMOLOGY AND HORTICULTURAL SCIENCE (1937, XV: 86-116), while the second is an unusually clear account of the building up of the " modified leader " apple tree, which is interesting fruit growers so much at the present time. The remarks on growth-principles and pruning practice should be read and considered by every student (in the widest sense) of fruit cultivation.

The last paper is an interesting contribution by an Inspector of the Board of Education on the place of school gardening in elementary and secondary schools.

The bonne-bouche of the publication has been left to the last, although it is the first paper in the volume. This is a reprint of an address delivered at the Revision Course by Mr. F. A. Secrett and entitled "A Pilgrimage of Fear ". A survey of thirty-five years of struggle in the market-garden industry by an acknowledged master, it is a delightful blend of piety and acumen, of scholarship and foresight, which should be read alike by the beginner and the expert.

It is unfortunate that, from motives of economy, it was found necessary to condense the plates together so that not only do those belonging to one paper come in the middle of another, but they may not even come in the correct relative order. It is to be hoped that in future issues of this useful journal, funds may permit of a more orthodox arrangement.

This publication should be in the hands of every student and grower ; few books can offer so much condensed information at so small a price.

R.H.S.

A REVIEW OF THE LITERATURE ON STOCK-SCION INCOMPATIBILITY IN FRUIT TREES, WITH PARTICULAR REFERENCE TO POME AND STONE FRUITS. By G. K. ARGLES. Foreword by Prof. V. H. Blackman, Sc.D., F.R.S. (Technical Communication 9 of the Imperial Bureau of Fruit Production, East Malling, Kent, England. 1937. pp. 113, bibl. 194. 5s.)

The problem of incompatibility has loomed ever larger with the increasing realization of the advantages to be gained by the use of tested clonal rootstocks as scion foundations for the production of uniformly excellent fruit.

The literature on the subject is considerable, but is so scattered that it is not always easy to consult. In it the term incompatibility is used extremely loosely, and may mean much or little. The author here briefly summarizes the phenomena which occur as the result of slight or pronounced incompatibility in different stock-scion combinations.

The horticulturist is often faced with the problem of growing fruit in places where there is no experience to guide him. If he knows that under

conditions in some respects resembling his own, certain rootstocks have given promising results with particular varieties, he has at least something on which to base his trials. As regards commercial deciduous tree fruits, he would be most unfortunate if he did not find some guidance in these pages.

The plant physiologist, moreover, has, in grafting and budding, a unique field for investigation, and the author gives him a firm basis on which to work.

First, the manifestations or symptoms of incompatibility are considered and their possible causes discussed. Next, the compatibility or incompatibility between individual varieties of common deciduous fruit trees and particular rootstocks is noted, considerable attention being paid to the field experience of research workers in different parts of the world. Lastly, certain general conclusions are drawn as to the symptoms and the causes of inherent incompatibility, and suggestions are made for drawing up a research programme.

In a 40 page appendix the many and often contradictory records of compatibility and incompatibility between particular rootstocks and scion varieties are tabulated. These should prove helpful not only to the plant physiologist but also to the practical fruit grower.

THE FRAMEWORKING OF FRUIT TREES. By R. J. Garner and W. F. Walker. (Occasional Paper 5 of the Imperial Bureau of Horticulture and Plantation Crops, East Malling, Kent, England,* 1938. pp. 19, bibl. 26. 1s.)

The authors set out briefly but intelligently the results of practical orchard experiments in Tasmania, England and elsewhere on methods of topworking and thereby changing the variety of fruit trees at will.

The method commonly accepted in the past has consisted—to put it somewhat crudely—in chopping off the top of the tree and grafting one or two scions into the stump, or into not more than the two or three branches which may remain. The method here described consists essentially in grafting a very large number of scions at the end of all the smallest branches. The labour involved is very much greater, but the return of the tree to productivity is much more rapid than by the older method, so that the one advocated would appear to make the practice worth while.

Four ways of carrying out the operation are described, namely, stub-grafting, side-grafting, inverted bark-grafting and awl-grafting. Clear line drawings greatly facilitate an understanding of the methods, while photographs showing an apple tree immediately after treatment and a similar tree two years after treatment, bearing five bushels of fruit, demonstrate the results which can be expected.

Possible difficulties, choice of grafting wax, costs and other practical points are all fully discussed.

D.A.

* From January 1938, the Imperial Bureau of Fruit Production was renamed the Imperial Bureau of Horticulture and Plantation Crops.